

209

131

**SSAB**

**F 10 B: 334**

**Bradford Residual Oil  
Athabasa Ft. McMurray**

### Undersökning av Californisk skiffer.

Från Californien anlände i maj 1951 ett skifferprov, förpackat i två säckar.

Provet krossades till 10-20 mm kornstorlek. Vid ytterligare nedkrossning visade sig skiffern vara mera lättkrossad än svensk skiffer.

#### 1. Analys av skiffern.

Spec.vikt = 1,32

Elementaranalys: C = 23,5 %, varav 0 % karbonatkol.

H = 3,35 %

S = 2,94 %

Askhalt = 61,2 %

Värmevärde: 2760 kcal/kg.

#### 2. Standardpyrolys.

2 kg skiffer upphettades i elektriskt uppvärmd retort till 550°C på 26 timmar. Med täta mellanrum uttogs gas- och oljeprover, vilka analyserades. Produktionen av olja, vatten och gas mättes en gång i timmen. Under försöket erhöles:

Olja: 175 ml/kg

Vatten: 5,6 ml/kg

Koks: 74,8 vikts %

Gas: 54,2 liter/kg.

Produktionen och produkternas sammansättning framgår av kurvblad 1-3.

Genomsnittssammansättning och egenskaper:

Olja: Spec.vikt 0,92

Svavel: 4,7 %

Jodtal: 113

paraffinpunkt: -24°C

destillationskurva (ASTM): se diagram 4.

Överdest. under 230°C = 27 volyms %.

Gas: Analys: (Gas från Fischerpyrolys)

H<sub>2</sub>S 9,6 %

CO<sub>2</sub> 2,8 %

CO 1,6 %

H<sub>2</sub> 24,7 %

C<sub>n</sub>H<sub>2n+2</sub>+N<sub>2</sub> 18,9 %

C<sub>n</sub>H<sub>2n</sub> 12,4 %

100,0 %

Värmevärde: 5620 kcal/Nm<sup>3</sup>

Koks:

C = 12,7 %

H = 1,0 %

S = 1,58 %

aska = 81,6 %

$W_{\text{kcal}} = 930 \text{ kcal/kg}$

Vatten:

Fenolhalt: 0,018 g/l

ammoniak: 2,9 g/l.

3. Askans smältpunkt.

Askans smältpunkt överensstämmer med Kvarntorpsskifferns.

4. Kaloribalans vid pyrolys av 1 kg skiffer.

Ing. kalorier: 2760. Utg. kalorier:	olja	1590
	gas	310
	koks	730
		2630
	diff.	130
		2760

5. Kommentarer och slutsatser.

Den californiska skifferns oljehalt är nära 3 ggr så hög som Kvarntorps-skifferns. Koksens värmevärde är högt och bör räcka för pyrolysens genomförande i Kvarntorparetorten. Någon sintring av askan har ej visat sig.

Beträffande produkterna må nämnas, att oljan har hög svavelhalt (1,7 %) och låg pour point ( $-24^{\circ}\text{C}$ ). Brytningsindex ligger högt (ca. 1,52), vilket tyder på hög halt aromatiska ämnen. Gasen har lägre svavelhalt än Kvarntorps-skifferns gas, men en ekonomisk utvinning av svavel torde vara möjlig. Pyrolysvattnet innehåller 2,9 g  $\text{NH}_3$  per liter, vilket icke torde räcka till för en ekonomisk utvinning av ammoniak.

Per ton torr, pyrolyserad skiffer erhålles:

166 kg råolja

0,18 kg  $\text{NH}_3$

8,25 kg svavel

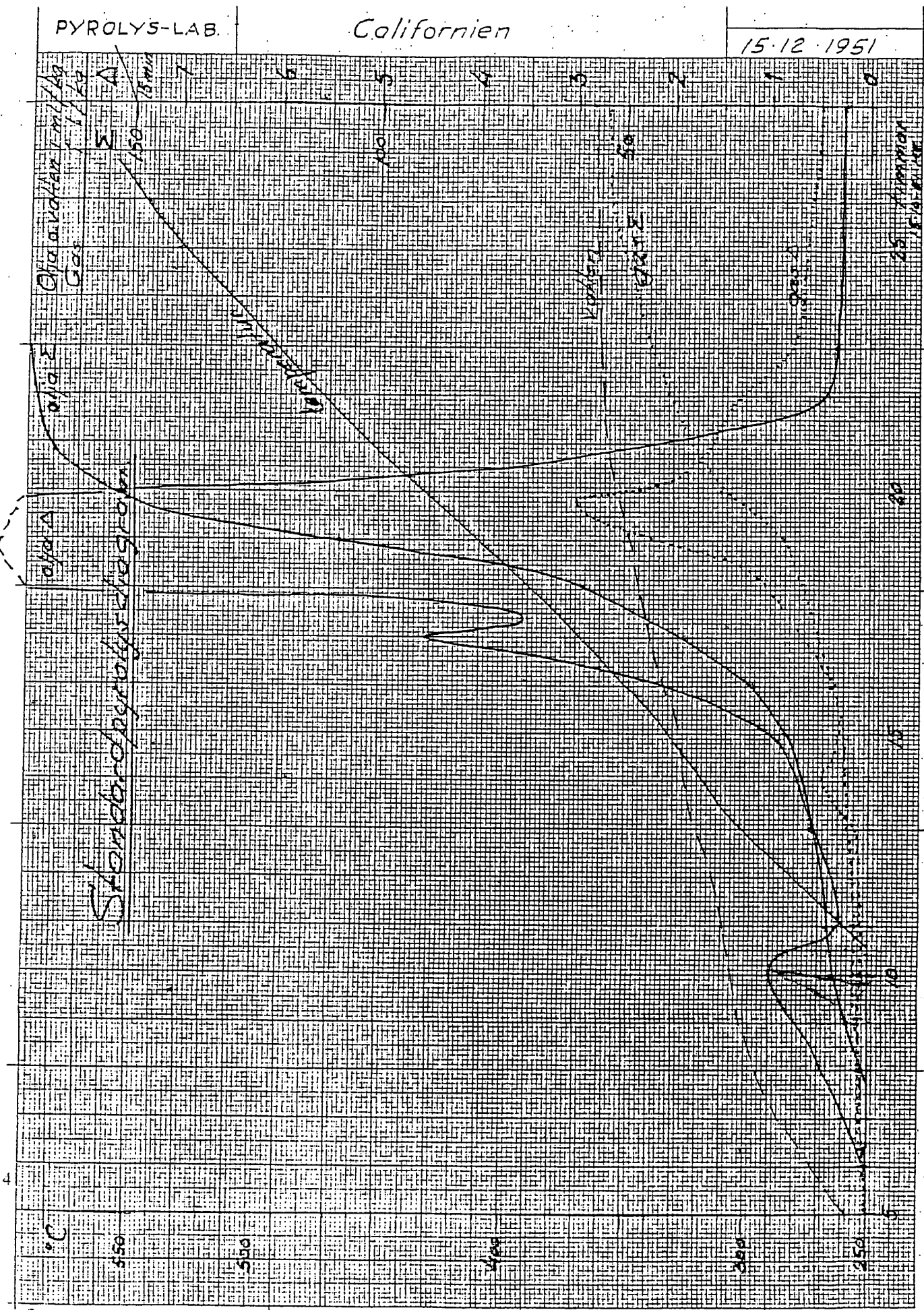
50,5 m<sup>3</sup> rengas.

Närkes Kvarntorp den 17.12.51.

*G. Salomonson*

13.25

Standardpyrolysegram





PYROLYS-LAB.

Californien

15.12.1951

*Olionsapenskopar*

bryls- spars  
maler vkt

100

105-0.99

104-0.98

103-0.97

102-0.96

101-0.95

100-0.94

20 30 40 50 60 70 80 90 100

100

100

90

80

70

60

50

40

30

20

21/1/52  
2.5.1951

ASTM-destillationskurva för

Californisk skifferolja

Tillhör rapport nr 105

från Pyrolyslaboratoriet

°C

400

380

360

340

320

300

280

260

240

220

200

180

160

140

120

100

80

60

40

20

0

0

10

20

30

40

50

60

70

80

90

100

öfverdest

Fdt. 61°C

10% 151°

20% 188°

30% 245°

40% 275°

50% 300°

60% 330°


max 68% 340°

spec. wgt. 0.92

Gränser för bensin enl. S. T. 31-normen.

Internt bolagsbrev

Svenska Skifferolje Aktiebolaget

Arende:	California-skiffer	MEDDELANDE		Reg.	
Avsändare: (avd. + namn)	ing. Salomonson	Till (avd. + namn)	Dir. Wiborgh	Nr	23/1 1952

Härmed översändes 2 ex. av vår rapport över undersökningarna å skiffer från Black Diamond Oil Co, Californien.

Kvantitetsproben borde vara användbara som jag tidigare sannoligen meddelat vid vår konferens i december.

Sal

Ankomstdatum

Örebro den 6 / 9 1950.

Hans Wiborgh

Från H.C. Wiborgh

Kopia till Direktör Gejrot,  
Direktör Gunnar W. Anderson.

3.5/11

Sul

Internt bolagsbrev

## Svenska Skifferolje Aktiebolaget

Ämne: \_\_\_\_\_

Till Professor Ed. Schjånberg,  
Närkes Kvarntorp.

En av Herbert Lindens kontakter, ett amerikanskt bolag  
Black Diamond Oil Company, förfogar över stora skifferfyndigheter.

Bolaget ifråga har per flyg sänt oss två säckar skiffer på  
sammanlagt 25 kg., som de ha bett oss analysera.

Jag vore därför tacksam, om Du ville låta undersöka skiffern  
samt överlämna en analys till undertecknad. Säckarna sändas ut  
till Dig personligen genom Fröken Norders försorg.

Örebro den 6 " 9 1950.

från H.C. Wiborgh

*H.C. Wiborgh*

Kopia till Direktör Gejrot,  
Direktör Gunnar W. Anderson.

1. Utländska skifferar. 1702/05

a. Colorado-skiffer.

Från tidigare försök med Colorado-skiffer i Rockesholms-ugnen (se förra årsredogörelsen) fanns kvar ett parti på 20-25 ton. Detta parti har använts för prov i experimentugnen (5 fack). Denna drevs som ett Bergh-fack med möjligheter till återföring av okondenserbar gas till koksschaktet. Proven skulle ge upplysning om koksen gick att bränna ut och hur snabbt förbränningen kunde ske utan risk för sintring samt om möjligt vilka utbyten, som kunde erhållas. Beträffande detaljerna hänvisas till en separat rapport.

Sammanfattningsvis kan meddelas, att vid en genomsättning, av upp till 200 kg skiffer/h och fack erhöles inga sintringar, men om denna ökades med 10 % inträdde allvarliga sådana. Om genomsättningen hölls så lågt som 110 kg/h (ca. 600 t. per Bergh-ugn och dygn) blev värmeutvecklingen per tidsenhet för liten för att tillfredsställande pyrolys skulle erhållas. Man ligger på gränsen för värmeverdet på den koks, som vid förbränning skall ge pyrolysvärmet. Återföring av okondenserbar gas till koksbädden misslyckades troligen på grund av olämplig brännareplacering. Tillräckligt material fanns icke för ytterligare undersökningar.

På grund av materialets grovhet (13-32 mm) inträffade ideligen hängningar och tendens till bakning av skiffern i retorterna förekom. Utbränningen var bra, men oljeutbytet icke högre än ca. 60 % räknat på Fischer. Gasen hade hög halt av  $\text{CO}_2$  (karbonat i skiffern) och låg halt av  $\text{C}_3$ - och  $\text{C}_4$ -kolväten. Dess värmeverde

- 2 -  
beräknades dock ligga omkring 4000 kcal/m<sup>3</sup>. Oljan hade en spec. vikt av 0,91  
med 18 % bensin och med 45 % kokande under 300 °C. Svavelhalten var 0,8 % och  
kvävehalten 1,9 %.

För att kunna fastställa de lämpligaste driftbetingelserna erfordras  
ytterligare minst 50 ton skiffer av rätt korntklass.

# Colorado-skiffer NR 107.

Skiffer 16.55 %C 1.89 %H medelt. 1305 cal/g

spec. vikt = 1.63 1.54 askhalt = 6.79 % svavel 0.41 %  
 $\text{CO}_2/\text{g} = 89.5$  karbonat C = 4.425 %

## Pyrolysis

### Standardretorten

### Fischer

### Proppyrolyso. p.

Olja 10.7 %

9.7 %

%

svavel 0.74 %

spec. vikt 0.879

pour point + 19°C

jordal. 75  
 kcal/g = 10138

Gas 23.5 Nm<sup>3</sup>/ton.

18.06 Nm<sup>3</sup>/ton.

Nm<sup>3</sup>/ton.

värmevärde 112.5 kcal/m<sup>3</sup>

kcal/m<sup>3</sup>

CO<sub>2</sub> + H<sub>2</sub>S 15.8 %

%

CO 3.2 %

%

O<sub>2</sub> 0.6 %

%

C<sub>n</sub>H<sub>2n</sub> 4.4 %

%

C<sub>n</sub>H<sub>2n+2</sub> 28.0 %

%

H<sub>2</sub> 98.0 %

%

N<sub>2</sub> 10.0 %

%

H<sub>2</sub>S 5.06 %

%

Koks. 84.6 %

87.51 %

C 9.37 %

H 0.31 %

värmevärde 102 kcal/g

askhalt 76.1

svavel. 0.49 %

Kondensvatten. 1.94 %

1.00

Luft. 9/6

rummorsol. 1.13



## Gasanalyse ent. PODBIELNIAK.

$H_2S = 5.0\%$	$n-C_4 = 1.4\%$
$CO_2 = 10.8 11.3\%$	$C_5 \text{ och högre} = 0.5\%$
$C_1 = 15.9\%$	<u><math>inert = 56.6\%</math></u>
$C_2H_4 = 0.7\%$	
$C_2H_6 = 4.9\%$	
$C_3H_6 = 1.3\%$	
$C_3H_8 = 2.0\%$	
$iso-C_4 = 0.5\%$	
$n-C_4 = 1.4\%$	
$C_5 \text{ o. högre} = 0.5\%$	

16,3

27,1

beräknat  
Weff =

## Gasanalyse ent. ORSAT-FRIEDRICH

$H_2S = 5.0\%$	$CO_2 = 11.3\%$	$CO = 3.3\%$	$H_2 = 39.2\%$	$N_2 = 18.1\%$	$C_nH_{2n} = 4.5\%$	$C_nH_{2n+2} = 28.9\%$
						100,0

50,3

33,4

## 3. Fischer-pyrolyse:

olja = 9.7% <sup>nikel-</sup>

Vatten = 1.0% <sup>nikel-</sup>

Gas = 18.1% <sup>litium-</sup>

Koks = 87.5% <sup>nikel-</sup>



Test run no. 2.

Test started: , finished: Duration of test: hours.

Retorting conditions:

Temperature A (see drawing)	900 °C =	°F
Temperature C ( - " - )	725 °C =	°F
Temperature of recirculated flue gas	230 °C =	°F
Steam admission	95 kg/h =	lbs/h
Steam temperature	340 °C =	°F
Steam pressure	1.32 atö =	psig
Raw shale charged	tons/day =	lbs/h
Fuel gas consumed	34.5 m <sup>3</sup> /h =	cuft/h
Fuel gas heating value (aver)	2820 kcal/m <sup>3</sup> =	BTU/cu.ft.

Condensing conditions:

Gas temperature before scrubber	93 °C =	°F
Gas temperature after tube condenser	°C =	°F
Crude oil produced	l/day =	gals/day
Crude gas produced	m <sup>3</sup> /h =	cuft/h
Water produced	l/h =	gals/h

Yields:

Crude oil	l/ton =	gals/ton
Crude oil % of Fischer assay =		%
Crude gas	112 m <sup>3</sup> /ton =	cuft/ton

Properties of products (see also separate table):

Crude oil: spec. gravity		° API
Crude oil: gasoline content (1200°C / 400°F)		% by volume
Crude gas: heating value (gross)	kcal/m <sup>3</sup> =	BTU/cu.ft.
Retort shale: heating value (approx.)	kcal/kg =	BTU/lbs.

Calorific balance: (basis 1 metric ton of shale)

Calories input:

Raw shale (combustion heat)	kcal/ton =	%
Admitted steam	" =	%
Fuel gas	" =	%

Total kcal/ton = 100 %

Calories output:

Retort shale (combustion heat)	kcal/ton =	%
Produced crude oil	" =	%
Produced crude gas	" =	%
Water from scrubber	" =	%
Not measured and losses (by diff.)	" =	%

Total kcal/ton = %

Nr	Datum	%olja	%vatten	%koks	Gas Nm <sup>3</sup> /ton	Anm.
1	31.8.48	28.72	4.28	59.52	82.61	
2	3.9.48	26.97	3.8	62.2	80.43	
3	9.9.48	29.96	3.9	62.50	82.78	

### Fischerdestillationer av Coloradoskiffer B

Nr	Datum	%olja	%vatten	%koks	Gas Nm <sup>3</sup> /ton	Anm.
1	14.9	7.13	1.6	89.52	15.22	Aukrokt 2 min för byta av gastub.
2	16.9	6.62	1.42	90.05	11.71	
3	18.9	1.45	1.7	89.25	13.22	

### Gasanalyser ent. Orsak. på gas från Coloradoskiffer A

Dest. 2	CO <sub>2</sub> + H <sub>2</sub> S	C <sub>2</sub> H <sub>2</sub>	O <sub>2</sub>	CO
↓	8.7%	6.3%	12.2%	0.6%
Dest. 3	6.4%	6.3%	12.6%	0.6%
Dubbelprov	6.4%	5.4%	12.5%	0.6%

Sept. - 48

G.E.

## Undersökning av Colorado-skiffern.

### 1. Skiffer.

Ur den stora sändningen Colorado-skiffer, 2300 säckar, vilka anlände till Kvarntorp i augusti 1951, uttogos prover ur tre säckar, placerade på olika ställen i det uppstaplade partiet. Vid Fischer-pyrolys visade sig de tre proverna ha överensstämmande egenskaper, varför den mera utförliga undersökningen inskränkte sig till ett av proverna.

Provet krossades till 10-20 mm kornstorlek. Vid ytterligare nedkrossning visade sig skiffern vara hårdare än svensk skiffer.

Spec.vikt: ca. 1,5

Elementaranalys: C = 16,55 % varav 4,48 % karbonatkol.

H = 1,89 %

S = 0,41 %

Askhalt: 67,9 %

Värmevärde: 1305 kcal/kg.

### 2. Standardpyrolys.

22.5 10 lbs 24 hours 1030 °F  
13 kg skiffer upphettades i elektrisk uppvärmd retort till 550 °C på 24 timmar. Med täta mellanrum uttogas gas- och oljeprover, vilka analyserades. Produktionen av olja, vatten och gas mättes en gång i timmen. Under försöket erhöles:

Olja: 107 ml/kg

Vatten: 1,9 vikts-% varav 0,1 % före 250 °C.

Koks: 84,6 vikts-%

Gas: 23,5 liter/kg.

Produktionen och produkternas sammansättning framgår av kurvblad 1-3.

Gemensnittssammansättning och egenskaper:

#### Olja.

Spec.vikt = 0,879 (se diagram 3).

svavel = 0,74 %

Jodtal = 75

pour point = 419 °C (mycket var i oljan!)

destillationskurva (ASTM) se diagram 4.

överdest. under 230 °C: 27 volyms-%.

#### Gas.

Analys: H<sub>2</sub>S = 5,0 %

CO<sub>2</sub> = 11,3 %

CO = 3,3 %

H<sub>2</sub> = 39,2 %

N<sub>2</sub> = 7,8 %

C<sub>n</sub>H<sub>2n</sub> = 4,5 %

C<sub>n</sub>H<sub>2n+2</sub> = 28,9 %

Värmevärde: W<sub>eff</sub> = 4290 kcal/M<sup>3</sup>

(ber. ur anal.)

475 BTU/ku

C<sub>1</sub> = 22,2 %

C<sub>2</sub> = 5,6 %

C<sub>3</sub> = 3,4 %

C<sub>4</sub> = 1,7 %

C<sub>5</sub> och högre

0,5 %



Koks. C = 9,37 %

H = 0,31 %

S = 0,49 %

aska = 76,1 %

$W_{\text{kcal}} = 102 \text{ kcal/kg}$

= 180 BTU/lb

Under pyrolysen hade koksen i viss grad bakat ihop sig, delvis till hårda, men relativt spröda klumpar.

Vatten. Fenolhalt = 0,03 g/l.

ammoniakhalt = 10,63 g/l

3. Fischerpyrolys: Olja = 9,7 vikts-%

Vatten = 1,0 vikts-%

Gas = 18,1 liter/kg.

Koks = 87,5 vikts-%.

4. Askans smältpunkt.

Askans smältpunkt ligger lägre än Kvarntorps-skifferns.

5. Kaloribalans vid pyrolys av 1 kg skiffer.

Ingående kalorier: 1305. Utgående kalorier: olja 1070

koks 86

gas 100

1257

diff. 48

1305

85 %

7 %

8 %

6. Kommentar och slutsatser.

Colorado-skifferns oljehalt är nära dubbelt så hög som Kvarntorps-skifferns. Koksens värmevärde är mycket lågt, och räcker ej till för pyrolysens genomförande i Kvarntorps-retorten. Även med hänsyn till koksens benägenhet att sindra ihop, ställer det sig tvivelaktigt om denna metod går att använda.

Beträffande produkterna må nämnas, att oljan har låg svavelhalt (0,74 %) och är på grund av hög vaxhalt praktiskt taget fast vid rumstemperatur. Den har ett relativt högt brytningsindex, vilket tyder på en hög halt ~~(ca 5 %)~~ <sup>(ca 5 %)</sup> aromatiska ämnen. Gasen har lägre svavelvätehalt än Kvarntorps-skifferns gas, men en ekonomisk utvinning av svavel torde vara möjlig. Pyrolysvattnet innehåller 10,6 g  $\text{NH}_3$  pr liter, vilket även torde vara tillräckligt för en ekonomisk utvinning av ammoniak.

Per ton pyrolyserad skiffer erhålles:

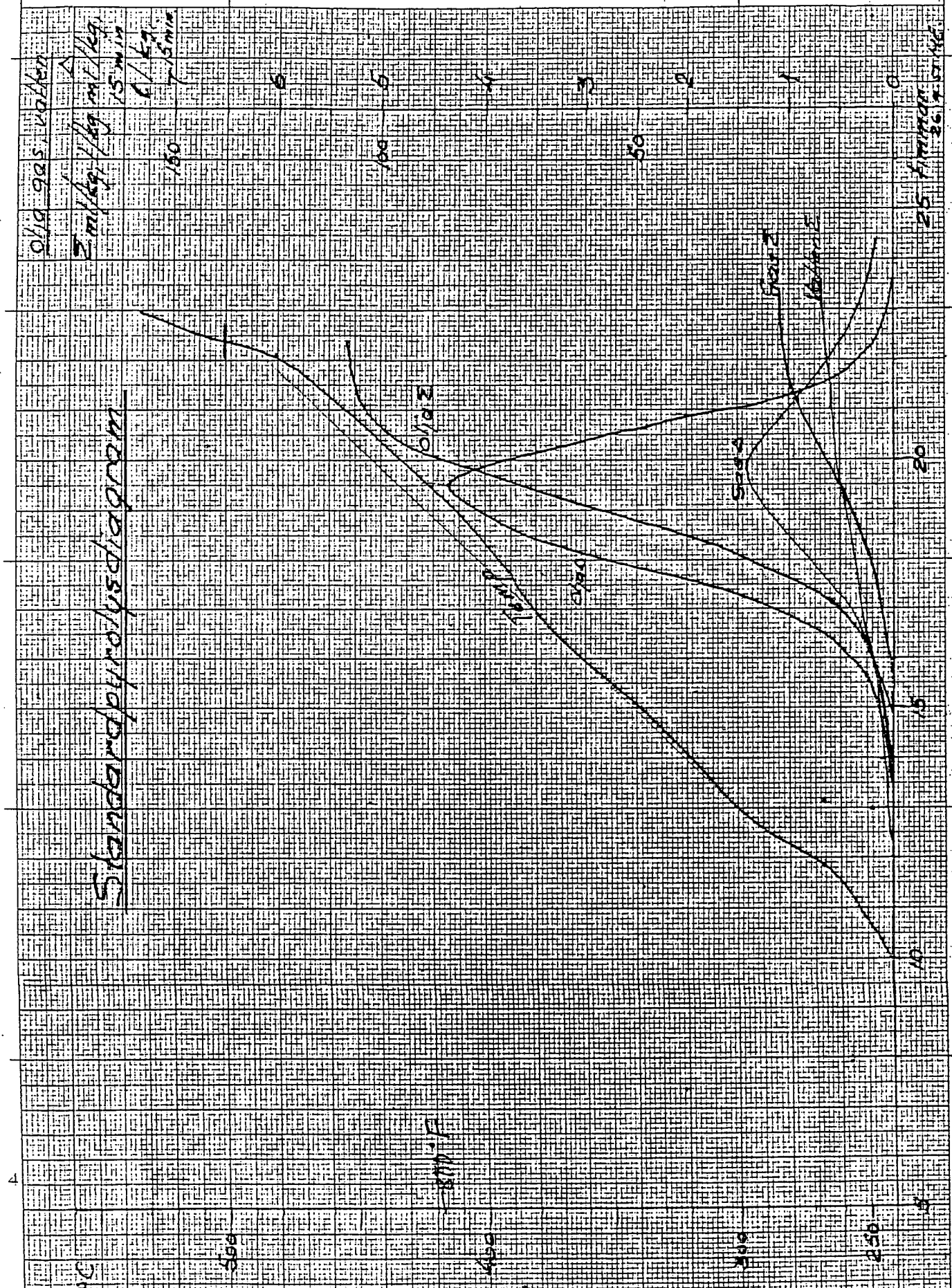
94 kg råolja

0,20 kg  $\text{NH}_3$

1,2 kg svavel

22,5 m<sup>3</sup> rengas.

Närkes Kvarntorp den 8.10.51.

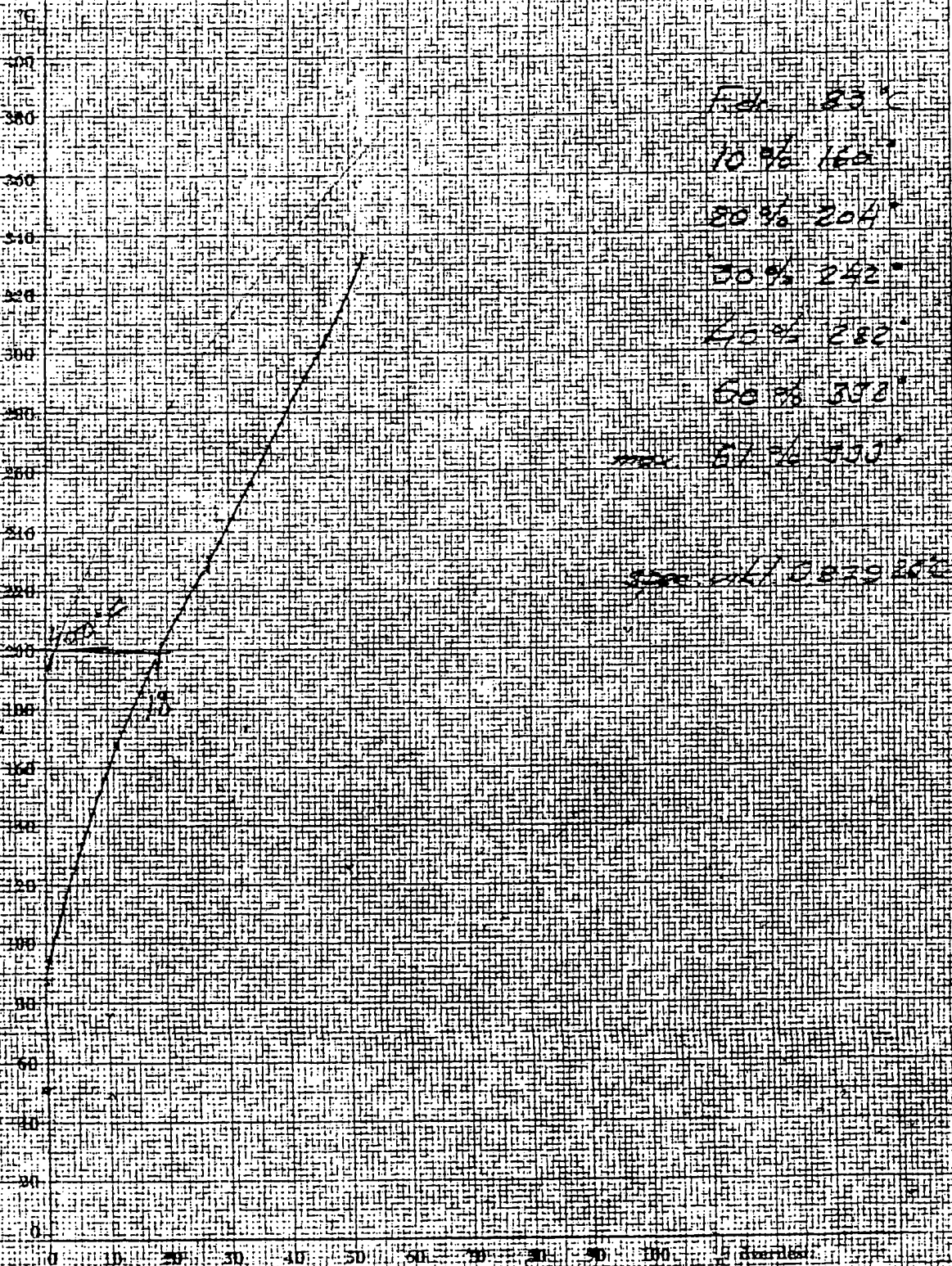






ASTM-distillationskurva för skifferolja från Colorado, USA

Tillhör rapport nr 107 från Pyrolyslaboratoriet



Summary of the intrareport on testing Green River oil shale from Colorado, U.S.A., in Bergh retorting process.

From the tests with Colorado oil shale in the HG retort there remained about 20 tons, which have been used in tests with the Bergh retorting process. Guiding for the decision to perform these tests was the following discussion:

When processing Swedish oil shale in Kvarntorp (Modified Bergh) units spent shale with a heating value of about 1250 kcal/kg of raw shale (2250 B.t.u. per pound of raw shale) is delivered to the combustion section from the retorts. This heat quantity leaves the unit as

shale ash	300 kcal/kg of raw shale	(560 B.t.u./lb)
steam from bed coils	380 kcal/kg raw shale	(675 " )
flue gas	430 kcal/kg of raw shale	(775 " )
endothermic heat and heat losses	140 kcal/kg of raw shale	(250 " )

Assume then that Colorado oil shale is processed in a Kvarntorp unit. The shale ash leaving the combustion section is assumed to have a heating value of  $\sim 75$  kcal/kg of raw shale (135 B.t.u./lb). The heat release during the combustion is several times less than at combustion of Swedish spent shale. The temperature in fuel bed is therefore low, which greatly affects the heat transfer (mainly radiation) to the steam producing coils. The steam generation will therefore be very low, and the presence of cooling coils only for steam generation is not justified. The flue gas volume is smaller when burning Colorado spent shale in comparison with Swedish spent shale, which means that a smaller quantity of heat,  $\sim 200$  kcal/kg (360 B.t.u./lb), is carried away by the flue gases. The heat duty for the Bergh process when processing Colorado shale should thus be  $75 + 200 + 140 = 415$  kcal/kg of raw shale (750 B.t.u./lb), and for the Kvarntorp process a little higher.

The spent shale from a Kvarntorp retort has a little higher heating value than that from the HG retort, and Colorado spent shale from a Kvarntorp retort can be assumed to contain at least 220 kcal/kg of raw shale (400 B.t.u./lb). Thus there is a deficiency of 195 kcal/kg (350 B.t.u./lb) in the heat duty, which can be covered by recirculation of the product gas and/or use of kerogen (incomplete pyrolysis). The product gas-calories from a Kvarntorp retort are about half the corresponding calories from a HG retort, or 180-200 kcal/kg of raw shale (325-360 B.t.u./lb). The Bergh or the Kvarntorp process therefore may be used for processing Colorado oil shale, if they are modified to utilization of the product gas for heating the retorts, too.

Use of cooling coils in the combustion section (Kvarntorp process) is only justified for purpose of temperature control when processing Colorado oil shale. The most interesting question to be answered is therefore:



How rapidly can Colorado spent shale be burned without cooling coils, as in the Bergh system, and without danger for caking? The tests should give an answer to this question. The yields of oil and gas that might be reached must only be a second hand-question, as the available quantity of shale was too small to determine also optimum operating data.

#### The test unit.

The test unit is an independently built box with 5 retorts, and belonging to this a condensing system. The box has nearly the same dimensions as an ordinary Kvarntorp-box, and is equipped with means to measure operating and production data. The product gas can be recirculated to the combustion section to be burned there. (Fig.)

#### The oil shale.

The Colorado oil shale has been stored outdoors in the original bags since its arrival in August 1951. At inspection the appearance of the shale was quite unaltered, and the mean Fischer assay-value was 9,6 % by weight of oil at the tests in april 1953 compared to 9,8 % at the tests in Febr. 1952.

The size of the shale, screened to minus 1 1/4" plus 1/2" at Rifle, is considered to be far from ideal. Average of the sieve analyses was:

+ 30	-30 to +26.7	-26,7 to +22,4	-22,4 to +16	-16 to + 10	-10 to + 6	-6 to + 4	- 4	mm square mesh
0,6	6,1	19,2	40,2	27,0	5,6	0,6	0,8	% by weight

The shale used at Kvarntorp is screened to minus 27 plus 5 mm and shall not contain more than 30 % plus 16 mm (compared to 66 % for the Colorado shale obtained).

#### The tests.

A series of tests with different shale throughputs was performed. The tests were mainly performed without use of product gas as additional fuel as the location of the gas burners in the combustion section was not successful. A corresponding amount of kerogen (incomplete pyrolysis) must then be used to meet the heat duty of the process, which will decrease the theoretical oil yields about 15 %.

The tests showed that the spent shale could be burned at a rate of up to 200 kg of raw shale/h (440 lb/h) without caking. At higher rates sintered cakes were formed that later blocked the discharging mechanism. At rates less than 100 kg of raw shale/h (220 lb/h) the heat release in the combustion section was too low to give good pyrolysis, which is indicated by low yields and low flue gas-temperature. The fire was sensible for disturbances of feed of spent shale. A steady descendance of shale pieces seems to be an important

a tendency of the shale to coke in the pyrolysis zone (about half way down in the retorts) was noticed. Sometimes hangings were formed, but they could be loosened with bars. However when the retorts had been emptied no trace of deposits on the retort walls was noticeable.

If Colorado shale of size, which is considered ideal, is processed, the upper limit of the throughput will probably be lowered a little.

The yields of oil were 55-65 % of the Fischer assay-value except for the extreme runs, when they did not exceed 50 %. At a gas yield of 40 Nm<sup>3</sup>/metric ton (1300 std. cuft/ton) a product gas with a gross heating value of 4000 kcal/Nm<sup>3</sup> (450 B.t.u./cu.ft) could be obtained. It contained about 20 % by vol. CO<sub>2</sub>, less than 1 % H<sub>2</sub>S and about 3 % C<sub>3</sub> + C<sub>4</sub>-hydrocarbons.

The shale ash contained only about 3 % of the original calories of the raw shale. Its heating value was about 40 kcal/kg of raw shale (70 B.t.u./lb). The carbonates decomposed considerably during the passage of the unit. At one of the middle runs with a throughput of 150 kg of raw shale/h (270 lb/h) about 15 % of the carbonates were decomposed in the pyrolysis zone and 60 % in the combustion zone.

The oil had a spec. gravity of 0,915 and had creamy consistency at 20°C (68°F). It distilled to 17-18 % by vol. overhead at 200°C (392°F) and 46 % at 300°C (572°F). Its sulfur-content was 0,8 % by weight and nitrogen-content 1,9 %. The analyses of an over all sample of the oil is shown in the table on next page. Compared to the oil produced of Colorado oil shale in the HG retort the oil is a little heavier.

The available quantity of 20 tons was not sufficient for determination of operating data to obtain maximum yields of oil and gas. For this purpose at least 50 tons more are required.

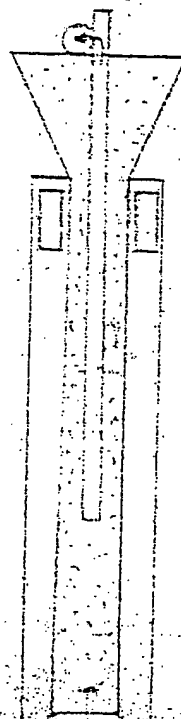
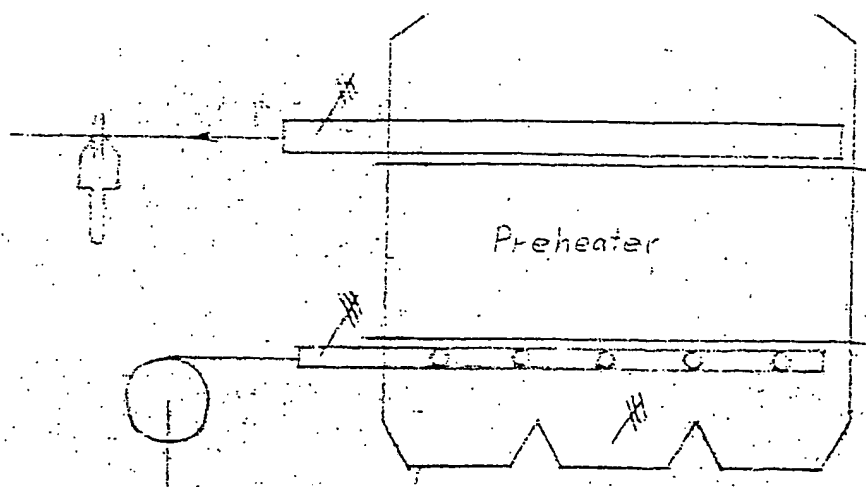
Närkes Kvarntorp in June, 1953  
Svenska Skifferolje AB  
Research Department

*B. Schjærberg*

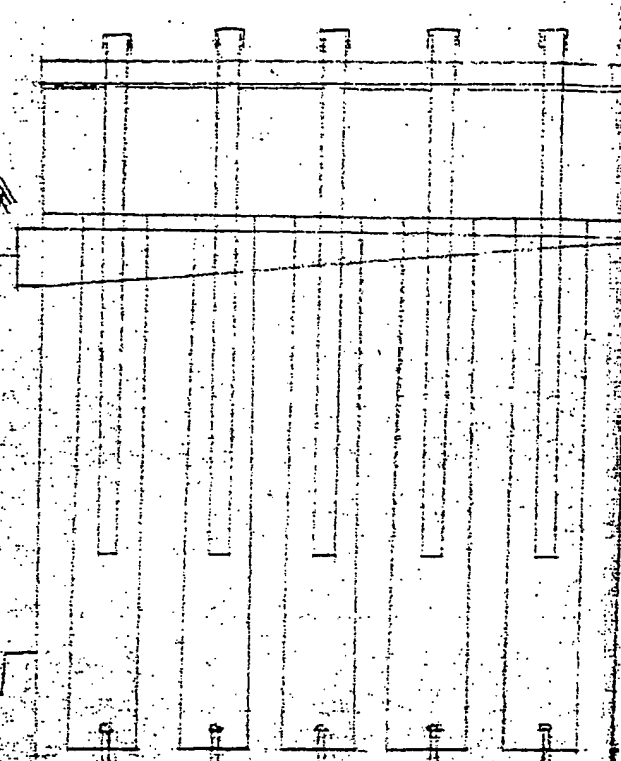
*Åke Brandberg*

Analyses of over all sample of oil.

Analysis	
Sp.gr. at 20°C	0,915
ASTM-dist. I.b.p. °C	65
5 % , °C	133
10 % , °C	165
20 % , °C	225
30 % , °C	263
40 % , °C	288
50 % , °C	307
60 % , °C	319
max. , °C	319
Overdist. at 200°C, %	17
at 300°C, %	46
H <sub>2</sub> O, %	0,6
Pour point, °C	+21
W <sub>gross</sub> kcal/kg	10170
% C	84,0
% H	11,50
% S	0,78
% N	1,86

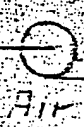


Air →  
Suction  
Combustion gases



Fuel gas

Hot water under pressure



A



Pyrolys och förbränning av Colorado-skiffer i Bergh-fack.

Från tidigare försök med Coloradoskiffer fanns ett parti på 20-25 ton kvar. Detta har använts för prov i experimentugnen, när denna var ordnad som Bergh-fack med möjligheter för återföring av okondenserbar gas till koks-schaktet. Proven skulle ge upplysning om koksen från Colorado-skiffern gick att bränna, och om hur snabbt förbränningen kunde ske utan risk för sintring samt om vilka utbyten som kunde nås.

Skiffern. Skiffern, som färdigkrossad och siktad anlände till Kvarntorp i augusti 1951, hade hela tiden varit lagrad utomhus i de ursprungliga säckarna. Till utseendet var skiffern oförändrad och inga spår av vittring syntes. Vid Fischer-analys erhöles under de nu genomförda proven 9,6 vikts-% olja som medeltal mot 9,8 % vid proven i febr. 1952.

Skiffern var i jämförelse med skiffer till Kvarntorp-ugnarna grov och var enl. uppgifter från Rifle siktad med 32 och 13 mm siktdukar. På uttagna skifferprover utförda siktanalyser gav följande medeltal:

+30	-	26,7	-	22,4	-	16	-	10	-	6	-	4	-	mm kvadratiska mas
0,6		6,1		19,2		40,2		27,0		5,6		0,6		kor
														vikts %

Över 16 mm ligger 66 % av godset mot önskvärt högst 30 % och fint gods saknas nästan helt.

Skifferns fukthalt var låg, 0,5 %.

Experimentugnen. Beträffande försöksanordningar, provtagning, etc. hänvisas till beskrivning i rapporten ang. motsvarande försök med Congo-skiffer.

Försöken. Försöken var avsedda att löpa i perioder om 2 dygn med olika genom-sättning. Störningar av olika anledningar gjorde att perioderna ibland blev för korta för att möjligt säkra balanser och utbytesberäkningar skulle kunna göras. Störningarna bestod mest av att utmatningen av aska ej fungerade tillfredsställande. Det grova godset byggdes upp som valv ovanför valsarna p.g.a. ineffektiv vibrering, och de så uppkomna hängningarna var svåråtkomliga. Det grova godset orsakade också ideliga hängningar i retorterna, och dessutom verkade det som om skiffern under pyrolysen "bakade" (mjuknade och svällde) och orsakade hängningar längre ned i retorterna. Med spett kändes dessa ställen som segt beck. Vid tömning av retorterna syntes dock inga spår av avsättningar på retortväggarna.

Start av facket kunde ske genom vanlig teknik med vedeldning. Luftmängden för förbränningen reglerades efter rökgasernas CO<sub>2</sub>-halt, och utsugen pyrolysgasmängd reglerades efter undertrycket i grenröret samt gasens kvävehalt. Undertrycket i rökpassschaktet hölls möjligast konstant. Medelvärden av drift- och produktionsdata för de olika perioderna framgår av tabell 1-3, och produktanalyserna återfinnas i tabell 4-9 (förutom de fullständiga Orsatanalyserna enl.

Under den första perioden (29-31/3 tabell 1) hölls en genomsättning på 95 kg/h. Härvid erhöles en relativt god fyr, men utbyten (49 % av Fischer-utbytet) och rökgastremperaturen (300°) visar att värmeutvecklingen per tidsenhet är i minsta laget. Försök gjordes att leda tillbaka okondenserbar gas och bränna denna i koksbad den men kort tid därefter märknade fyrarna och pyrolysen försämrades. Dagen efter upprepades försöket med samma resultat. Om försämringen av fyrarna beror på gastillsatsen eller på annan samtidig omständighet kan ej sägas. En sådan verkan av tillsats av brännbar gas (ehuru CO<sub>2</sub>-rik) synes märklig. Man skulle kunna tänka sig att gasen skapar en het zon längre ner i bad den dit förbränningen av koksen sedan också flyttas.

Under andra perioden (31/3-1/4, tabell 2) var genomsättningen något högre, 109 kg/h, dock ej så mycket som avsett. Fyrarna flammade mer än tidigare och syntes i genomsnitt vara märkare än i början av första perioden, men rökgastremperaturen var högre, upp mot 400°C. Olje- och gasutbytena hade också stigit det förra till 64 % av Fischervärdet.

Under båda dessa perioder erhöles endast ett koksprov med avsevärd "oljehalt", vilket kan synas märkligt med hänsyn till att pyrolysen knappast kan ha varit fullständig med så låga utbyten och ofta starkt flammande fyrar. Man får nog ej lägga för stor vikt vid koksproverna, då de äro svåra att taga ut på ett representativt sätt. Oftast får man kanske koks från retortens perifera delar och ej tvärsnittsprover.

Pyrolysgasens kvävehalt var hög, i medeltal 55-60 %. Den egentliga (rökgasfria) pyrolysgasmängden var därför bara 15-20 Nm<sup>3</sup>/ton. Gasens CO<sub>2</sub>-halt varierade starkt med fyrutseendet, 10-30 % CO<sub>2</sub>, vid nøyaktig pyrolys 20-25 %. Drygt hälften av koldioxiden torde härstamma från karbonatsönderdelning och resten till största delen från rökgasen. Analyserna på skiffer och koks tyder på att cirka 10 % av karbonaterna sönderdelats under pyrolysen i retorterna, och askanalyserna visa att knappt hälften återfinnas osönderdelade i askan.

Luftöverskottet vid förbränningen var väl stort. CO<sub>2</sub>-halten i rökgaserna var i medeltal 5,5 % men till dessa bidrager karbonatsönderdelningen med en dryg procent.

Askans utbränning var god. Endast 0,5-0,6 % av ursprungliga 12 % organiskt kol återstod i askan.

Under tredje perioden (22/4) skulle en genomsättning på 150 kg/h hållas men störningar i utmatningen inträffade redan efter mindre än 1 dygn. En god fyr (ofta flammande) erhöles emellertid och den visade inga sintringstendenser. Man kunde nu liksom förut lägga märke till att fyren är beroende av en jämn tillförsel av brännbart material. Skulle av någon anledning denna tillförsel mankera (störning i askutmatningen, hängningar, avknagningar, tillförsel av för kalorifattig koks) försämrades fyren snabbt och kunde ofta inte fås normal igen utan yttre hjälp. Ang. olje- och gasutbytena kan inget bestämt sägas, då mätperioden var för kort. Uppskattningsvis erhöles cirka 8-9 l olja/h eller

mindre än tidigare och luftmängden uppgick till 1,5-2 Nm<sup>3</sup>/kg skiffer, varvid rökgasens CO<sub>2</sub>-halt blev omkring 9 %. Baddtemperaturen var otvivelaktigt högre än under föregående perioder och karbonatsönderdelningen livligare.

Nästa period startades med hög genomsättning, cirka 220 kg/h. En mycket livlig förbränning erhöles som ledde till svårartade sintringar efter 12 h drift och efter 1 dygn måste ugnen släckas på grund av hinder för askutmatningen. Luftmängden var ~1,9 Nm<sup>3</sup> luft/kg skiffer varvid CO<sub>2</sub>-halten i rökgasen på 10-12 % erhöles. Karbonatsönderdelningen var livlig; askanalysen visar att högst 15 % av karbonaterna finnas osönderdelade i askan. Även i retorterna var karbonatsönderdelningen kraftig, 40 % sönderdelas i dessa. Ej heller under denna period kan säkra soppgifter om olje- och gasutbyte lämnas. Oljeutbytet torde dock ej ha överstigit 50 % av Fischerutbytet. Vid gasuttag på ~50 Nm<sup>3</sup>/ton erhöles, när pyrolysen gick som bäst, gas av god kvalitet och högt värmevärde, ~4500 kcal/Nm<sup>3</sup> (Tabell 8 analyserna 24/4 kl. 09.40-14.10).

Den sista perioden var avsedd att ha en genomsättning på 175 kg skiffer/h. Den oberäknliga askutmatningen gav först en genomsättning på 200 kg/h under 15 h (approx. 55 % oljeutbyte och 55 m<sup>3</sup> gas/ton av god kvalitet, tabell 8 analyserna 26/4 03 och 09.45), varefter utmatningen krånglade (dock ej p.g.a. sinter) och gav till slut en period på 1 dygn med en genomsättning av 150 kg/h. Efter störningarna i utmatningen, då genomsättningen periodvis varit mycket låg, måste fyren på nytt startas genom vedeldning. För den avslutade perioden om 1 dygn kan en approximativ balans uppställas enl. tabell 3. Oljeutbytet var 61 % av Fischerutbytet. Koksanalyserna indikera ofullständig pyrolys. Askans utbränning var god, och ~75 % av karbonaterna hade sönderdelats (~15 % i retorterna).

Oljeutbytena har beräknats på medelvärdena av Fischer-analyserna under försöken, nämligen 10,2 % för försöken i slutet av mars och 9,0 % i slutet av april. Variationerna i analyserna är avsevärda, vilket ansetts bero på heterogena prov. Alla ovan angivna utbyten inkluderar ej gasbensinen. Medräknas denna ökas procentuella utbytet med ~2 %.

Oljeanalyserna (tabell 7) är högst varierande, vilket förklaras av att proverna, som samlats dygnsvis, ej alltid håller tung- och lättolja i bildade proportioner p.g.a. den intermittenta tömningen av oljan ur de stora mätankarna för lättoljan + vattnet. Ett generalprov av all bildad olja har därför tagits och analyserats (tabell 7).

#### Sammanfattning.

Den vid försöken använda skiffen var olämplig vad beträffar korngraderingen (sällad med 13 och 32 mm:s säll). Denna skiffer kunde pyrolyseras och förbrännas i Bergh-fack med en hastighet av 200 kg/h utan allvarligare sintringar. Vid genomsättning av 220 kg/h erhöles kraftiga sintringar. Med genomsättningar under 110 kg/h blev å andra sidan värmeutvecklingen per tidsenhet för liten för att erhålla tillfredsställande pyrolys. Fyrän syntes vara mycket känslig för störningar. En jämn tillförsel av brännbart material



är ett olrankomligt villkor och det är tydligt att man har ligger på en gräns för värmevärdet på den koks, som skall brännas för att ge pyrolysvärme. Försök med återföring av okondenserbar gas till koksbedden gav ej goda resultat, förmodligen p.g.a. olämplig brännarplacering i bädden. Ett stöd för fyren genom gaseldning vore mycket önskvärt för att göra den mindre känslig. Gaskalorierna utgör 1/3 till 1/2 av kokskalorierna.

I retorterna orsakade det grova materialet ideliga hängningar, och skiffern visade tendens till att baka och därigenom hänga sig längre ned i retorterna.

Askans utbränning var mycket god. Dess värmevärde var  $\sim 50$  kcal/kg, vilket motsvarar mindre än 3 % av skiffrens kalorier. Minst hälften av karbonaterna i skiffern sönderdelas vid passagen genom facket, vilket är en svår belastning.

Uthytene av olja låg vid 55-65 % av Fischervärdet (inkl. gasbensin) utom vid högsta och lägsta genomsnittningen då det ej översteg 50 %. Vid ett gasuttag på  $40 \text{ m}^3/\text{ton}$  bör ett värmevärde på  $4000 \text{ kcal/m}^3$  erhållas. Gasen kommer att hålla  $\sim 20$  %  $\text{CO}_2$  och föga  $\text{C}_3\text{-C}_4$ -kolväten.

Oljan hade en spec.vikt av 0,915 och var vid rumstemperatur ej flytande. Den destillerar till 17-18 % under  $200^\circ\text{C}$ , till cirka 46 % under  $300^\circ\text{C}$  och 60 % kunde destilleras över innan sönderdelning började. Dess svavelhalt är  $\sim 0,8$  % och kvävehalt 1,9 %. Jämfört med den Colorado-olja, som framställdes i HC-retort, är den något tyngre (0,02 högre spec.vikt), har större del högkokande beståndsdelar och högre stelningpunkt.

Närkes Kvarntorp 1 maj 1953.

FD/ABg

Table 1.

Material and heat balances for Bergh retorting system on basis of 1 metric ton raw shale.

Test run with Colorado-shale (29.3.07-31.1. 14 1953) Throughput 95 kg/h.

Material	Temperature °C	Spec. heat mean value	Gross heat value	Quantity		Heat, Mcal	
				Kg	Nm <sup>3</sup>	Sensible	Latent
In Raw shale (0,5 % moisture)	5	-	1410	1000	-	-	1410
Steam, 2,5 ata	150	-	-	210	-	140	-
Air	5	-	-	-	2650	-	-
Total							1550
Out ksh	50	0,3 <sup>x</sup>	25 <sup>x</sup>	770	-	10	20
Oil	40	0,5 <sup>x</sup>	10150 <sup>x</sup>	50	-	-	510
Water	40	1 <sup>x</sup>	-	85	-	-	-
Pyrolysis gas	25	-	(2300) <sup>xx</sup>	-	63	-	145
Flue gas	300	0,32 <sup>xx</sup>	75 <sup>xx</sup>	-	2650	255	200
Carbonate decomposition	-	-	-	-	-	-	-
Calorific losses	-	-	-	-	-	-	-
Total							335
							1550

x per Kg  
xx per Nm<sup>3</sup>

Table 2.

Material and heat balances for Bergh retorting system on basis of 1 metric ton raw shale.

Test run with Colorado-shale (31/3 23-1/4 23 1953) Throughput 109 kg/h

Material	Temperature °C	Spec. heat mean value	Gross heat value	Quantity		Heat Mcal	
				kg	Nm <sup>3</sup>	Sensible	Latent
In							
Raw shale (0.7 % moisture)	5	-	1410	1000	-	-	1410
Steam, 2.5 ata	150	-	-	250	-	165	-
Air	5	-	-	-	2400	-	-
Total							1575
Out							
Ash	50	0.3 <sup>x</sup>	25 <sup>x</sup>	770	-	10	20
Oil	45	0.5 <sup>x</sup>	10150 <sup>x</sup>	65	-	-	660
Water	45	1 <sup>x</sup>	-	75	-	-	-
Pyrolysis gas	25	-	(2200) <sup>xx</sup>	-	80	-	175
Flue gas	(400)	0.32 <sup>xx</sup>	50 <sup>xx</sup>	-	2400	305	120
Carbonate-decomposition	-	-	-	-	-	-	-
Calorific losses	-	-	-	-	-	-	-
Total							1575

x per kg

xx per Nm<sup>3</sup>

Table 3.

Material and heat balances for Bergh retorting system on basis of 1 metric ton raw shale,  
Test run with Colorado-shale (27/4 15-28/4 06 1953) Throughput 150 kg/h

Material	Tempera- ture °C	Spec. heat mean value	Gross heat value	Quantity		Heat, Mcal		
				kg	Nm <sup>3</sup>	Sensible	Latent	Total
In								
Raw shale(0,4 % moisture)	5	-	1330	1000	-	-	-	1330
Steam, 2,5 ata	150	-	-	205	-	135	-	135
Air	5	-	-	-	1900	-	-	-
Total								1465
Out								
Ash	50	0,3 <sup>x</sup>	60 <sup>x</sup>	740	-	10	45	55
Oil	45	0,5 <sup>x</sup>	10000 <sup>x</sup>	55	-	-	550	550
Water	45	1 <sup>x</sup>	-	54	-	-	-	-
Pyrolysis gas	25	-	(2500) <sup>xx</sup>	-	63	-	155	155
Flue gas	(400)	0,32 <sup>xx</sup>	45 <sup>xx</sup>	-	1900	240	85	325
Carbonate=decomposition	-	-	-	-	-	-	-	110
Calorific losses	-	-	-	-	-	-	-	270
Total								1465

x per Kg

xx per Nm<sup>3</sup>

Table 4.

## Analysis of raw shale.

Date	28/3	29/3	30/3	31/3	1/4	21/4	22/4	24/4	26/4	27/4
Fischer assay:										
oil, % by weight	10,1	10,5	10,4	10,4	9,4	9,8	8,6	9,1	7,9	9,8
coke, " "	85,8	84,8	84,8	84,0	87,0	86,9	86,6	87,2	89,7	86,3
H <sub>2</sub> O, " "	1,5	1,4	1,8	1,3	1,4	1,3	2,5	1,5	1,5	1,7
Moisture = " "	0,5	0,5	0,4	0,7	0,8	0,4	0,5	0,4	0,3	0,4
Ignition loss, % by weight of dry sample	"	32,2	31,3	34,3	31,2	27,8	29,9	31,3	31,0	30,4
total C, % by weight of dry sample	17,76	18,61	15,48	19,13	16,93	16,63	17,08	16,12	15,28	15,52
carbonate C, " "	4,66	4,79	4,92	5,08	5,02	4,92	4,78	4,63	4,92	4,65
H, " "	2,11	1,88	1,79	2,26	2,07	1,92	2,05	1,87	1,71	1,75
W <sub>gross</sub> , kcal/kg dry sample	1490	1395	1235	1605	1340	1320	1415	1340	1260	1305

Table 5  
Analysis of shale coke.

Date	29/3	30/3	31/3	1/4	21/4	22/4	24/4	26/4	27/4
Fischer assay:									
oil, % by weight	0,1	0,2	2,3	0,1	1,4	0,3	0,1	0,2	0,2
coke, % " "	99,0	98,6	95,8	99,0	93,6	95,9	94,3	95,0	95,9
H <sub>2</sub> O, % " "	0,6	0,5	1,5	0,6	0,2	0,1	0,4	1,2	0,3
Moisture, " "	0,2	0,2	0,2	0,2	4,3	3,6	4,6	3,5	0,4
Ignition loss, % by weight of dry sample	23,0	23,4	21,9	22,7	14,6	23,0	15,4	22,1	20,6
total C, % by weight of dry sample	8,56	9,86	8,36	8,13	10,40	8,44	6,71	7,44	8,55
carbonate C " "	5,28	5,38	4,50	5,29	4,27	4,66	3,37	4,59	4,37
H " "	0,59	0,58	0,74	0,56	0,75	0,72	0,61	0,66	0,70
W <sub>gross</sub> kcal/kg dry sample	260	280	215	225	570	345	315	270	410

Table 6,  
Analysis of shale ash.

Date	29/3	30/3	31/3	1/4	21/4	22/4	24/4	26/4	27/4
Ignition loss, % by weight	6,5	14,2	12,0	14,8	11,0	4,3	3,6	5,4	5,6
total C, % by weight	2,06	4,54	3,99	4,59	3,56	1,39	1,47	1,79	1,86
carbonate C, % - "	1,71	3,67	3,38	3,62	2,52	1,12	0,88	1,46	1,55
H <sub>2</sub> , % - "	0,31	0,46	0,42	0,39	0,51	0,33	0,32	0,33	0,37
W <sub>gross</sub> kcal/kg	15	35	0	55	90	20	85	55	60

Table 7.  
Analysis of shale oil.

Date	30/3	31/3	1/4	23/4	24/4	26/4	27/4	Over all sample
Sp.gr. at 20°C	0,922	0,902	0,886	0,948	0,942	0,912	0,923	0,915
ASTM-dist. I.b.p.°C	57	73		74		58		57 <sup>x</sup>
5 %°C	201	90		211		99		127
10 %°C	252	141		244		151		159
20 %°C	-	201		-		183		208
30 %°C	-	233		-		219		240
40 %°C	-	263		-		254		-
50 %°C	-	-		-		269		-
60 %°C	-	-		-		-		-
max °C	-	-		-		-		-
Overdist. at 200°C, %	5	20		4		25		18
at 300°C, %	-	-		-		-		-
H <sub>2</sub> O, %	0,4	1,4	8,2	0,4	3,7	1,1	3,4	0,6
Pour point, °C	+24	+24	+21	+24	+21	+15	+24	+21
W <sub>gross</sub> kcal/kg	10160				9810			10170
% C <sub>9</sub>	84,0				82,1			83,98
% H	14,12				11,05			11,50
% S	0,85				1,00			0,78
% N <sub>9</sub>	-				-			1,86

x on electrically heated air-bath

xx gas heated.



## Analysis of pyrolysis gas,

[illegible]

the gas not combustible in Junker-calorimeter,

Table 8, (cont'd)

## Analysis of pyrolysis gas,

[illegible]

: the gas not combustible in Junker-calorimeter.

Table 9.  
Analysis of flue gas.

Date	29/3	30/3	20/4	31/3	1/4	22/4	24/4	26/4	27/4
Time	13 <sup>00</sup>	10 <sup>30</sup>	20 <sup>40</sup>	08 <sup>20</sup>	13 <sup>15</sup>	10 <sup>30</sup>	10 <sup>00</sup>	14 <sup>15</sup>	11 <sup>05</sup>
CO <sub>2</sub> by vol	6.0	4.2	8.0	2.6	3.8	8.8	12.6	3.4	3.9
O <sub>2</sub> by vol	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
H <sub>2</sub> by vol	14.2	15.8	9.4	17.4	16.0	11.8	9.8	16.6	16.1
CO by vol	0.2	0.2	0.6	0.0	0.1	0.2	0.0	0.6	0.0
H <sub>2</sub> by vol	0.4	0.4	0.4	0.2	0.4	0.4	0.2	0.6	0.2
C <sub>n</sub> H <sub>2n+2</sub> by vol	0.6	0.8	0.2	0.2	0.3	0.0	0.0	0.0	0.4
N <sub>2</sub> by vol	78.6	78.6	81.4	79.6	79.4	78.8	78.0	78.8	79.4

TESTING OF COLORADO (GREEN RIVER) OIL SHALE AT  
KVARNTORP, SWEDEN.

- I. Mining, crushing and sampling report from Rifle (Copy).
- II. Report on the testing of Colorado (Green River) Oil shale  
in the HG-retort at Kvarntorp, Sweden.

## Colorado Oil Shale Shipped to Sweden.

Sampling throughout the crushing operation was extensive as it was thought that a complete and reliable analysis of shale would be important in a case such as this. A total of 58 samples was taken - 12 of the minus 1 1/4" plus 1/2" as crushed into the storage bins; 12 of the minus 1/2" fines as produced while crushing the 180 tons of product; and 34 truck load samples of the minus 1 1/4" plus 1/2" taken as the shale was blended simultaneously from the three storage bins for haulage to the stockpile area.

Average Fischer assay values for the samples taken are as follow:

1. Minus 1 1/4" plus 1/2" as crushed into the 3 storage bins	26.67 gal/ton
2. Minus 1 1/4" plus 1/2" as blended from the bins into the 34 truck loads	26.69 gal/ton
3. Minus 1 1/2" plus 1/2" as a composited sample of the 34 truck loads	26.74 gal/ton
4. Minus 1/2" fines to waste while producing the minus 1 1/4" plus 1/2"	24.99 gal/ton

### 1) Mining.

At the request of the Processing Section the Oil Shale Mine Branch blasted nine diamond drill holes through the 70 foot Mahogany ledge in the vicinity of 637 raise. The holes were detonated in two separate blasts. Shale hauled to the crushers from the first blast amounted to roughly 300 tons and shale hauled from the second blast amounted to about 200 tons. The first 78 tons of the first blast was prepared by the crushing plant for use in pilot plant operations. The remaining 222 tons of the first blast was crushed and stockpiled for shipment to Sweden. The first 55 tons hauled from the second blast was also crushed and added to the Swedish stockpile. The remaining tonnage from the second blast (145 tons) was prepared by the crushing plant for pilot plant operations.

The average grade of the 70 foot section in the vicinity where this work was conducted is 27 gallons per ton. This value was established by means of assays on a diamond drill core taken at the time 637 raise was being driven. Assays of this core are tabulated in the Oil Shale Data Book.

-----  
1) This section of the memo was prepared by Homer Ballinger of the Mining Section.

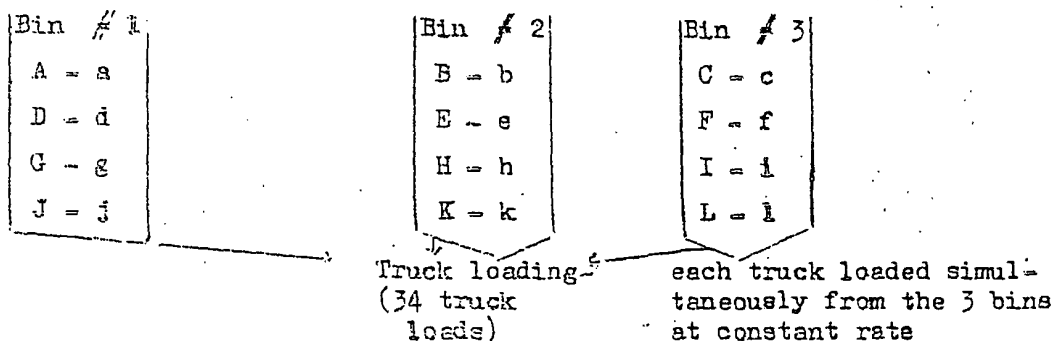
### Crushing and sampling.

All three crushers were used to prepare the shale. The primary jaw crusher was set at  $3 \frac{7}{8}$  open,  $3 \frac{1}{8}$  closed; the secondary hammermill at a rotor speed of 425 r.p.m., 5" spacer bars, and the breaker plate at its maximum distance from the hammers; the tertiary gyratory was set at  $1 \frac{1}{4}$ " on the closed side.

Both double deck vibrating screens were used with the  $1 \frac{1}{4}$ " cloths on the top decks and the  $\frac{1}{2}$ " cloths on the bottom decks. The material flow was as follows: from the primary crusher to the primary vibrating screen - the oversize going to the hammermill for secondary reduction, the product made in the primary crusher going to the bins, and the fines going to waste. The discharge of the hammermill went to the secondary vibrating screen - the oversize going to the gyratory for third stage reduction and closed cycle back to this same screen. The product and fines from this secondary vibrating screen joined the corresponding streams from the primary screen.

Both product and fines were sampled - the fines by the automatic sampler on conveyor No. 9 and the product by use of a flop gate operated manually at the head end of conveyor No. 2 while entering the bins, and by a flop gate operated manually at the head end of conveyor No. 13 while blending the shale from the bins into the trucks.

The shale was crushed alternately into the 3 bins, 15 tons at a time until each bin contained 60 tons. After this, it was blended simultaneously from each of the bins to trucks for haulage to the stockpile area. Samples were taken of each 15 tons into the bins, of the fines produced for each 15 tons, add of each truck load as it was loaded by simultaneous blending from the bins. Sampling was thus to obtain as good an analytical cross-section of the material as possible. The following is a diagram of this procedure:



Each capital letter, A through L, designates each 15 tons of material crushed, being crushed in alphabetical order and positioned as shown. Each small case letter, a through l, designates the fines associated with each 15 tons crushed. The trucks are designated 1 through 34 as in the order in which they were loaded.

Data

The following tables present the analytical results of the samples taken.

Minus 1 $\frac{1}{2}$ " plus  $\frac{1}{8}$ " 70-foot bed as crushed into storage bins

Sample description 1)					Crushing plant sample No.	Fischer assay gal./ton
1st	15 tons crushed into bin	#1	(A)		CPI-68	27.24
2nd	" " " " bin	#2	(B)		" -69	25.68
3rd	" " " " bin	#3	(C)		" -70	27.77
4th	" " " " bin	#1	(D)		" -74	27.50
5th	" " " " bin	#2	(E)		" -75	25.95
6th	" " " " bin	#3	(F)		" -78	Sample accidentally destroyed
7th	" " " " bin	#1	(G)		" -79	25.90
8th	" " " " bin	#2	(H)		" -80	25.40
9th	" " " " bin	#3	(I)		" -81	26.70
10th	" " " " bin	#1	(J)		" -82	25.40
11th	" " " " bin	#2	(K)		" -83	27.50
12th	" " " " bin	#3	(L)		" -84	28.30
Average					-	26.67

1) Capital letters correspond to those on diagram under "Procedure".

Minus 1 $\frac{1}{2}$ " plus  $\frac{1}{8}$ " 70-foot bed as withdrawn from storage bins

Sample description					Crushing plant sample No.	Fischer assay gal./ton
1st	truck load of 34	withdrawn			CPI-92	24.36
2nd	" " " "	"			" -93	24.89
3rd	" " " "	"			" -94	25.42
4th	" " " "	"			" -95	25.15
5th	" " " "	"			" -96	24.36
6th	" " " "	"			" -97	25.68
7th	" " " "	"			" -98	24.10
8th	" " " "	"			" -99	25.94
9th	" " " "	"			" -100	25.94
10th	" " " "	"			" -101	24.89
11th	" " " "	"			" -102	25.94
12th	" " " "	"			" -103	25.94
13th	" " " "	"			" -104	26.98
14th	" " " "	"			" -105	26.21
15th	" " " "	"			" -106	26.21
16th	" " " "	"			" -107	26.98
17th	" " " "	"			" -108	26.21
18th	" " " "	"			" -109	27.24
19th	" " " "	"			" -110	26.74
20th	" " " "	"			" -111	26.21
21st	" " " "	"			" -112	27.24
22nd	" " " "	"			" -113	27.77
23rd	" " " "	"			" -114	27.50
24th	" " " "	"			" -115	27.77
25th	" " " "	"			" -116	29.09
26th	" " " "	"			" -117	27.77
27th	" " " "	"			" -118	27.77
28th	" " " "	"			" -119	27.77
29th	" " " "	"			" -120	28.05
30th	" " " "	"			" -121	27.24
31st	" " " "	"			" -122	28.50
32nd	" " " "	"			" -123	28.50
33rd	" " " "	"			" -124	28.50
34th	" " " "	"			" -125	28.56
Average					-	26.69



Table 2. - Screen analysis - Minus  $1\frac{1}{4}$ " plus  $\frac{1}{2}$ " 70-foot bed as crushed into storage bins

Sample description 2)		Crushing plant sample No.	-.131	-.185 to .131	-.263 to .185	-.371 to .263	-.525 to .371	-.742 to .525	-1.05 to .742	-1.25 to 1.05	Total %
1st 15 tons crushed into bin #1 (A)		CPI-68	2.3	1.4	0.9	4.2	18.3	28.2	41.4	3.3	100.00
2nd " " " " bin #2 (B)		" -69	3.2	1.9	1.3	3.2	15.4	23.7	37.8	13.5	100.00
3rd " " " " bin #3 (C)		" -70	2.8	0.7	1.4	4.1	15.2	29.6	36.5	9.7	100.00
4th " " " " bin #1 (D)		" -74	1.3	0.4	0.4	3.5	17.5	29.0	40.4	7.5	100.00
5th " " " " bin #2 (E)		" -75	0.6	0.6	0.6	2.6	17.5	28.7	39.7	9.7	100.00
6th " " " " bin #3 (F)		" -78	sample accidentally destroyed								
7th " " " " bin #1 (G)		" -79	1.8	0.9	0.9	1.8	19.5	29.2	39.7	5.2	100.00
8th " " " " bin #2 (H)		" -80	1.6	0.8	0.8	2.5	17.3	30.0	41.8	5.0	100.00
9th " " " " bin #3 (I)		" -81	2.8	1.4	1.4	4.2	15.5	26.8	46.0	1.4	100.00
10th " " " " bin #1 (J)		" -82	1.1	1.1	1.1	2.2	15.6	24.4	42.3	12.2	100.00
11th " " " " bin #2 (K)		" -83	2.0	1.0	1.0	3.0	14.9	26.7	44.5	6.9	100.00
12th " " " " bin #3 (L)		" -84	4.6	2.8	4.6	6.4	14.7	22.0	38.5	6.4	100.00
Average			2.20	1.19	1.32	3.44	16.51	27.12	40.78	7.44	100.00

1) Cumulative screen analysis of minus  $1\frac{1}{4}$ " plus  $\frac{1}{2}$ " 70 foot bed as crushed into the storage bins

-.131	-.185	-.263	-.371	-.525	-.742	-1.05	-1.25
2.20	3.39	4.71	8.15	24.66	51.78	92.56	100.00

1) Based on averages from above table.

2) Capital letters correspond to those on diagram under "Procedure"

Minus  $1\frac{1}{4}$ " plus  $\frac{1}{2}$ " 70-foot bed as withdrawn from storage bins

2nd truck load of 34 withdrawn	CPI-93	1.9	2.4	1.2	5.6	21.1	28.6	33.0	6.2	100.00
11th " " " " " "	" -102	1.8	1.2	1.2	4.9	17.0	33.6	33.6	6.7	100.00
21st " " " " " "	" -112	2.2	1.4	0.7	3.6	15.3	32.2	35.1	9.5	100.00
31st " " " " " "	" -122	2.5	1.7	1.7	4.2	11.7	20.0	44.0	14.2	100.00
Average		2.10	1.68	1.20	4.58	16.27	28.60	36.42	9.15	100.00

3) cumulative screen analysis of minus  $1\frac{1}{4}$ " plus  $\frac{1}{2}$ " 70-foot bed as withdrawn from storage bins

-.131	-.185	-.263	-.371	-.525	-.742	-1.05	-1.25
2.10	3.78	4.98	9.56	25.83	54.43	90.85	100.00

3) Based on averages from above table

NOTE: Only 4 truck loads of 34 blended were analyzed for screen size because of lack of time.

Table 3. - Screen analysis and Fischer assay  
Minus 1" fines 70-foot bed while producing minus 1 1/4" plus 1" product.

Sample description 2)	Crushing plant sample No.	-.065	-.093 to +.065	-.131 to +.093	-.185 to +.131	-.263 to +.185	-.371 to +.263	-.500 to +.371	total %	Fischer assay gal./ton
Fines while crushing 1st 15 tons	CPI-71	27.6	9.4	9.4	13.4	16.5	18.2	5.5	100.00	25.42
" " " 2nd "	" -72	21.8	7.8	8.3	14.6	15.5	18.4	13.6	100.00	24.89
" " " 3rd "	" -73	22.1	8.6	8.6	12.9	18.2	21.5	8.1	100.00	25.15
" " " 4th "	" -76	30.0	9.0	9.0	12.4	14.1	17.6	7.9	100.00	23.06
" " " 5th "	" -77	21.5	7.9	8.7	15.9	17.3	20.6	7.9	100.00	26.21
" " " 6th "	" -85	19.9	6.6	9.6	15.4	19.1	23.5	5.9	100.00	27.20
" " " 7th "	" -86	29.5	8.2	9.8	15.0	16.5	17.2	3.8	100.00	24.90
" " " 8th "	" -87	27.0	4.7	10.1	15.5	17.8	20.2	4.7	100.00	24.60
" " " 9th "	" -88	29.0	7.7	10.3	14.8	17.5	16.2	4.5	100.00	24.60
" " " 10th "	" -89	30.5	8.7	11.2	14.9	14.9	15.5	4.3	100.00	24.10
" " " 11th "	" -90	28.9	8.3	9.8	14.4	15.9	18.2	4.5	100.00	24.40
" " " 12th "	" -91	29.4	8.5	10.5	11.1	16.4	18.5	5.6	100.00	25.40
Average		26.44	7.95	9.61	14.19	16.06	18.80	6.36	100.00	24.99

1) Cumulative screen analysis of minus 1" fines 70-foot bed while producing minus 1 1/4" plus 1" product.

-.065	-.093	-.131	-.185	-.263	-.371	-.500
26.44	34.39	44.00	58.19	74.85	93.65	100.00

1) Based on averages from above table

2) Small case letters correspond to those noted on diagram under "Procedure".

Crushing Information:

- 1) Total minus 1 1/4" plus 1/2" produced = 180.72 tons
- 2) Total minus 1/2" fines produced = 93.20 tons
- 3) Total crushing time = 11 hrs., 0 min.

Then, Fines loss

$$= \frac{93.20}{180.72 + 93.20} \times 100 = 33.68\%$$

.99 4)

and, Crushing rate

$$= \frac{180.72}{11} = 16.43 \text{ tons/hr.}$$

- 1) Weight obtained by use of conveyor scales on conveyor No. 2.
- 2) Weight obtained by use of conveyor scales on conveyor No. 9.
- 3) Represents total actual crushing time - obtained by use of stop watch.
- 4) Assuming 1 percent dust loss + loss of total mine run handled.

Table 5.

Summary of average Fischer assay values (compiled from foregoing tables)

Average of:

1) 1 - Minus 1 1/4" plus 1/2" as crushed into the storage bins	26.67 gal./ton
2 - Minus 1 1/4" plus 1/2" as blended into the 34 truck loads	26.69 "
3 - Minus 1 1/4" plus 1/2" as a composited sample of the 34 truck loads	26.74 "
4 - Minus 1/2" fines to waste while producing the minus 1 1/4" plus 1/2"	24.99 "

- 1) This average is not absolutely correct since one of the 12 samples on which the average should be based was destroyed.

CONCLUSION

No attempt has been made to analyze or make any conclusions concerning the analytical results herein, but merely to present the methods used for preparation and sampling and the tabulated results for sake of permanent record.

W.H. ECKERSON

Report on the testing of Colorado (Green River) Oil Shale in the HG-retort  
at Kvarntorp, Sweden.

Introduction.

In order to study the behavior of Colorado shale in the Swedish shale retorts an investigation was arranged and performed in cooperation between U.S. Bureau of Mines, the "Denver Group" (headed by Mr. Carl Norgren) and the Swedish Shale Oil Company.

The tests were made at the Swedish Shale Oil Co's works at Kvarntorp, Sweden. A quantity of about 140 tons of shale was prepared and shipped to Kvarntorp, packed in tight bags, by U.S. Bureau of Mines. A detailed report on the mining, crushing, screening and mixing of the shale is included as an appendix to this report.

The laboratory tests on the shale were made during 1951. In accordance with the conclusions from the obtained results it was determined that the full-scale retorting tests should be performed in the HG-retort system. One of the retorts of the HG-oven was selected for this purpose and was equipped with separate condensing equipment. The full-scale retorting was made in February, 1952, in the presence of Mr. John W. Savage, representing Savage Shale Oil Development Company and the Denver Group and Mr. R. Beverly, representing U.S. Bureau of Mines.

The results of the runs are presented in this report, which contains the following parts:

1. A summary of the laboratory investigations on the Green River oil shale.
2. A short description of the HG-retort.
3. Description of the test runs with Green River oil shale.
  - a) The retort and the condensing system.
  - b) Sampling, Methods of analysis.
  - c) The test runs: operating data; results of analysis; yield; heat and material balances; operating experience.
4. Summary of the test runs.

1. Summary on the investigations on Green River oil shale at the pyrolysis department of the laboratory.

Samples of the shale were taken out from three arbitrarily chosen bags and assayed according to Fischer. As they showed consistent properties the further investigation was done on one of the samples.

Results:

Fischer assay:

Oil 9,7 % by weight  
Water 1,0 %  
Shale coke 87,5%  
Gas 18,1 liter/kg

Ash content:

67,9 % by weight. The melting point of the ash is lower than that of Kvarntorp shale ash.

Elementary analysis:

C 16,55 % by weight (including 4,48 % C as carbonate)  
H 1,89 %  
S 0,41 %

Heat value(gross):

1305 kcal/kg

Standard pyrolysis.

5 kg. of the oil shale (size 10-20 mm) was heated electrically in a steel retort to 550°C in 24 hours (diagram 1), while the production of oil, gas and water was measured (Diagram 1). The following amounts of products were obtained:

oil: 107 ml/kg  
water: 1,9 % by weight  
(0,7 % at temp:s lower than 250°C)  
shale coke: 84,6 % by weight  
gas: 23,5 liter/kg

Properties of the products:

Oil:

Spec. gravity (aver.) 0,879 g/ml (diagram 3)  
Sulphur: 0,74 % by weight  
Iodine number: 75  
Pour point: +19°C  
ASTM-distillation: See diagram 4.

Gas:

Composition (of total). See also diagram 2.

H <sub>2</sub> S	5,0 % by volume	
CO <sub>2</sub>	11,3 %	
CO	3,3 %	
H <sub>2</sub>	39,2 %	
N <sub>2</sub>	7,8 %	
C <sub>n</sub> H <sub>2n</sub>	4,5 %	including
C <sub>n</sub> H <sub>2n+2</sub>	28,5 %	
		C <sub>1</sub> 22,2 % by volume
		C <sub>2</sub> 5,6 %
		C <sub>3</sub> 3,4 %
		C <sub>4</sub> 1,7 %
		C <sub>5+</sub> 0,5 %

Heat value(net, calculated): 4290 kcal/Nm<sup>3</sup>

Shale Coke:

Elementary analysis: C = 9,37 % by weight (incl. 5,1 %  
H = 0,31 % C as carbonate)  
S = 0,49 %

Ash content = 76,1 %

Heat value(gross): 100 kcal/kg(measured)

During the pyrolysis the shale coke had partly baked to hard but brittle cemented pieces.

Water:

Phenol content: 0,03 g/liter

Ammonia content: 10,6 g/liter

Calorific balance: Basis 1 kg oil shale

In: 1305 kcal	Out: oil	1070 kcal
	shale coke	86
	gas	101
		<hr/> 1257
	difference	<hr/> 48
		1305 kcal

Comparison with Kvarntorp oil shale.

The "oil content" of Green River oil shale is about twice as high as that of Kvarntorp shale.

The heat value of Green River spent shale (shale coke) is very low and is certainly too low for performance of the pyrolysis in the Kvarntorp-retort. Its baking tendency is another reason why the use of the Kvarntorp-retort is doubtful.

Compared with Kvarntorp oil the Green River oil has a low sulphur content, a very high pour point because of its high wax content, and the high refractive value indicates a high percentage of aromatics.

The gas contains much less  $H_2S$ , and the pyrolysis water has a higher  $NH_3$ -content.



## 2. Description of the HG-retort, and how it works with Kvarntorp shale.

The design of the retort is clear from the drawings. The slightly conical retort (upper diam 600 mm, lower diam. 720 mm) is in its lower part made of chamotte bricks, and in the upper part of chrome-alloyed iron. The retort-volume is about  $3 \text{ m}^3$  ( $\sim 3$  tons shale). The hopper above is connected to the retort through an oil-seal, and holds about 6 tons shale. The top of the hopper is covered with a lid forming a water seal with the hopper. The hopper is charged from a belt conveyor (steel) common to all 72 retorts of the bench. Low pressure steam is injected as a seal against atmosphere during the charging operation. A rotating arm (with controllable rate) on a plate discharges the retort to a hopper which is intermittantly emptied to a car, carrying the coke to the coke combustion plant. The pyrolysis gases from all retorts are sucked off through a pipe by one suction-blower.

Superheated steam is injected in the lowest part of the retort in order to reduce the vapor pressure (steam distillation) and the retention time of the oil vapors in the hot pyrolysis zone. The steam also serves the purpose of sealing the retort from incoming air during the discharging of the hopper.

Each retort has one gas-burner, where end gases from the light hydrocarbon recovery plant are burned. The flue gases pass through a helical canal around the retort and then through a superheater for steam (common to four retorts). Part of the flue gases are recirculated to the gas-burner by a blower in order to save the chamotte bricks and to increase the gas velocities.

The temperature of the retort is controlled by two pyrometers in the flue gas canal outside the retort, one (A-point) just behind the gas-burner inlet and one (C-point) 2,80 meters above the A-point.

Normal operating data are: Charging raw shale: every fourth hour, in total 11 metric tons (size 27-70 mm) per retort and 24 h. Temperatures: A-point  $\sim 1000^\circ\text{C}$ . C-point  $\sim 750-800^\circ\text{C}$ . Discharging the coke hopper: every hour. Consumption of low pressure steam (saturated,  $120^\circ\text{C}$ ): 120 kg/h. Consumption of fuel gas:  $34 \text{ m}^3/\text{h}$ . Temperature of recirculated combustion gases:  $210-250^\circ\text{C}$ . Vacuum in the discharge pipe for pyrolysis gases: 20 mm water.

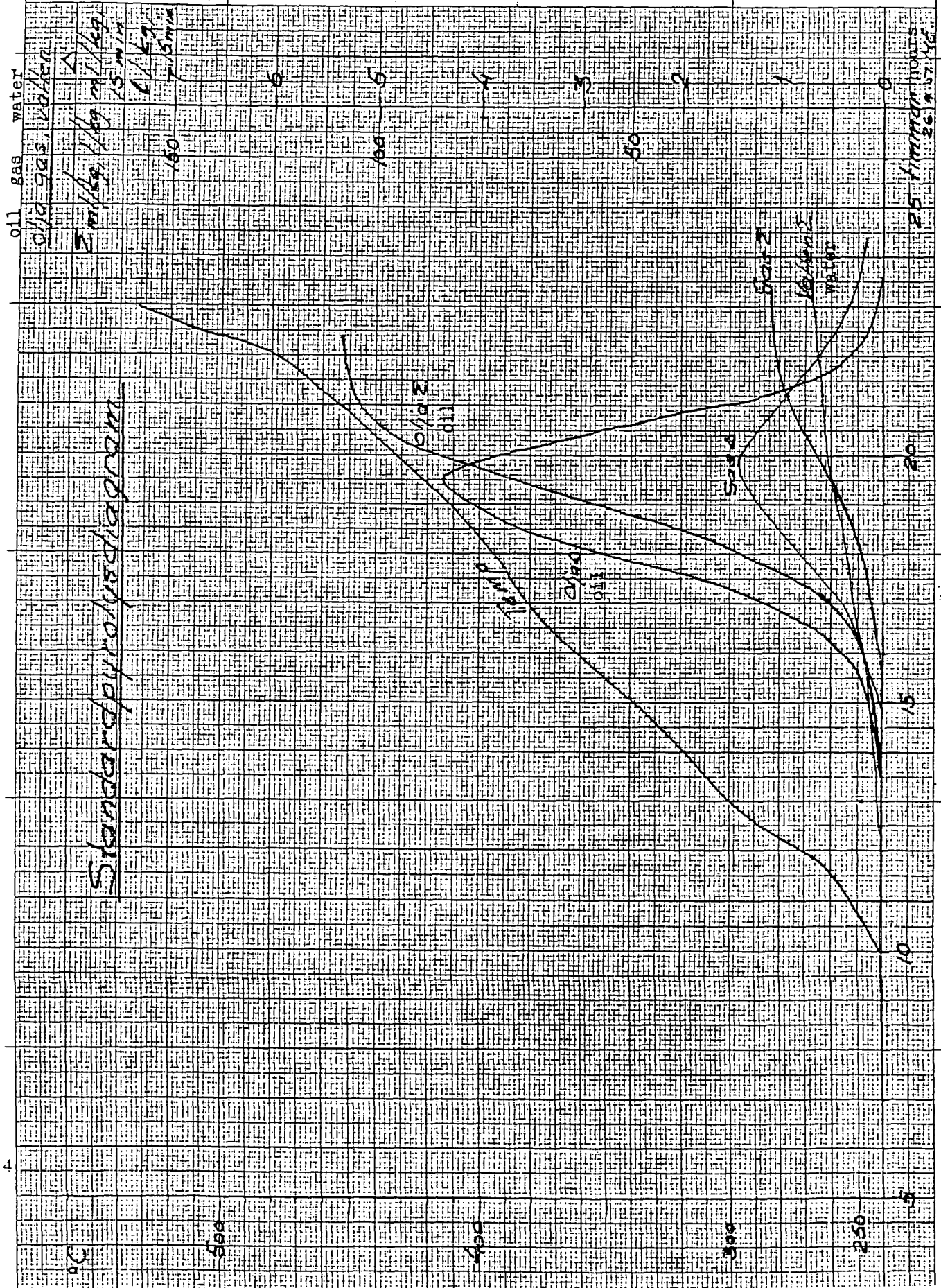
The following average consumption and production data were obtained during a normal production period (1.9. 1951 - 29.2. 1952).

<u>Consumption:</u>	<u>Per retort and hour</u>	<u>Per metric ton of raw shale</u>
Raw shale	460 kg	1000 kg
Steam (satd., $120^\circ\text{C}$ )	121 kg	262 kg
Fuel gas (a $3500 \text{ kcal/m}^3$ )	$34 \text{ m}^3$	$74.5 \text{ m}^3$
Corresponding calories	119.000 kcal	259.000 kcal
Cooling water (mostly circulated water from cooling towers).	4,15 ton	9,0 ton

Pyrolys-lab.

Pyrolys av Colorado-skiffer.

4.10.1951.





Fyrolys-lab.

Fyrolys av Colorado-skiffer.

4.10.1951.

Gas content (%)

Solens sammensetning ved pyrolyse av Colorado-skiffer

Colorado-skiffer

40-60 wt.-%

gas

gas

100

1/59

35

30

25

20

15

10

5

0

0

Properties of oil.

Oljans egenskaper

refractive index

brytningsindex

specific gravity

spec. gravitet

ref. index

brytn. spec. vikt  
index 80.0°

1.20 0.99

1.53 0.92

1.51 0.91

1.50 0.90

1.49 0.89

1.48 0.88

1.47 0.87

25.0 0.82

Barb.

194

Kontr

194

194

194

194

194

194

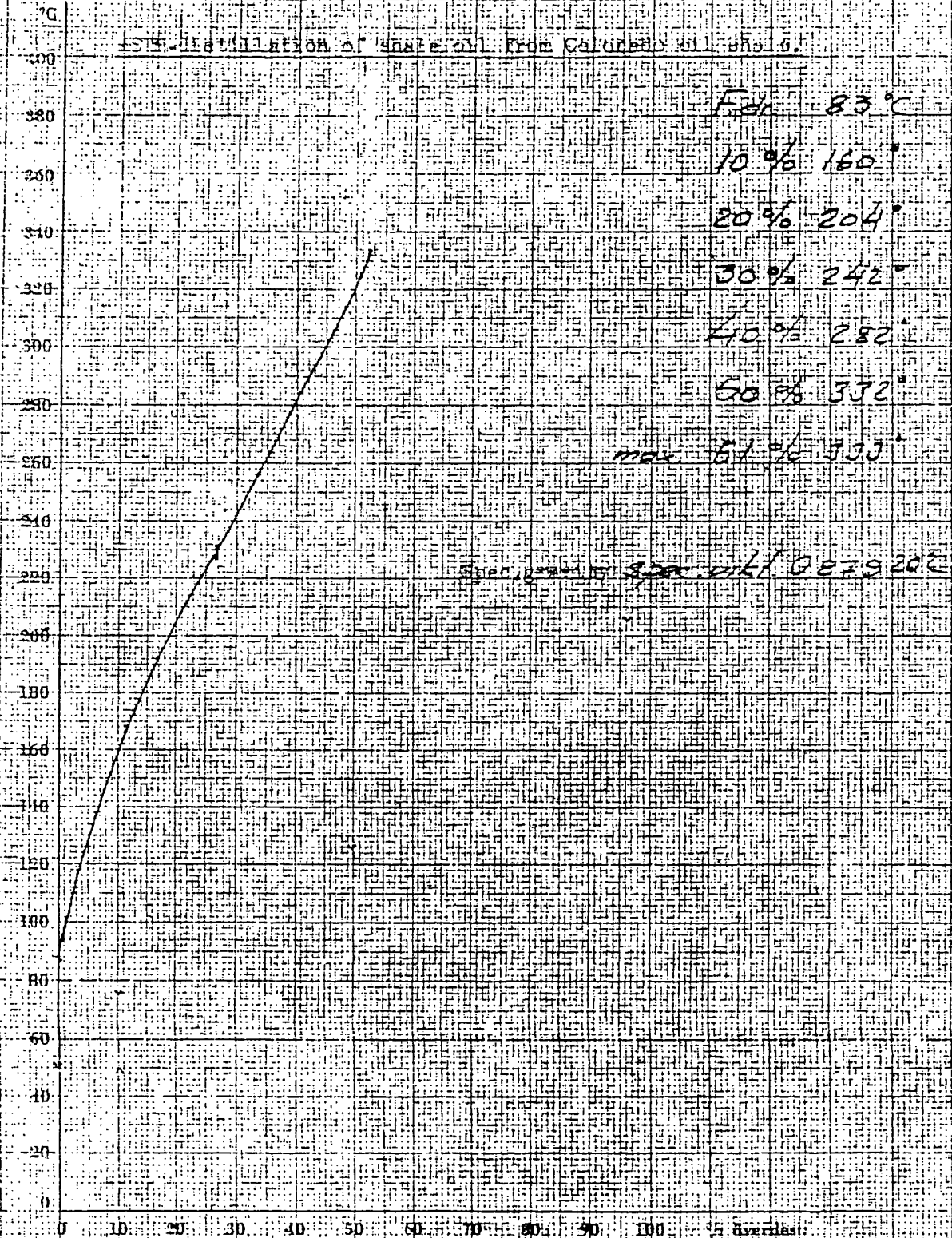
194

194

194

ASTM-distillationskurva för skifferolja från Colorado USA

Tillhör rapport nr 107 från Pyratylaboratoriet



✓ gränser för brand och S. T. F. nummer



<u>Production:</u>	<u>Per retort and hour</u>	<u>Per metric ton of raw shale</u>
Crude oil	20,5 kg	44,6 kg
<u>Light gasoline</u>	<u>3,4 kg</u>	<u>7,4 kg</u>
Total oil	23,9 kg	52,0 kg
Crude gas	39 m <sup>3</sup>	84,5 m <sup>3</sup>

Yield: The average "oil content" of the shale according to the Fischer assay was 5,75 % by weight. The total yield of oil was thus 90,6 % of the Fischer value.

### 3. The test runs with Green River oil shale.

#### a) The retort, the condensing system and its control.

The retort chosen for the tests was situated in the middle of the 72 retort bench.

As the size of the Green River shale, 13-32 mm, was much smaller than that of Kvarntorps shale, 27-70 mm, the discharge mechanism had to be reconstructed. A trial without alterations resulted in free fall of the shale through the retort. The alterations, which are clear from the drawing 13-10, caused that the through-put could not be raised to more than 7 tons/24 h, although the speed of the rotating arm was increased from  $\frac{1}{5}$  to 1 revolution/min. This depended on too small an opening above the arm and on the properties of the spent shale (small pieces and much dust in which the arm did not work efficiently).

An expected greater pressure drop because of the smaller size of the Green River shale was meant to be counteracted by placing an open 4" tube of 6 m length inside the retort. Its upper end was near the pyrolysis gas discharge pipe, and the tube was supported by three rods attached to the top of the hopper. The tube, however, became clogged by coked dust and oil as inspection after the tests showed, and its role during the test was supposedly none.

A flow sheet for the retort and the condensing equipment is shown in drawing nr. 13-199. The pyrolysis gases went through a 5" pipe to a scrubber (drawing nr 13-197), where they were counter-currently washed with water, and then to a tube-condenser, where they were cooled to 10°C or lower. The gas flow was caused by a suction blower after the tube condensor, and from the blower the gases went to a flare.

The water and oil from the scrubber were delivered to a settling tank from which part of the water-oil suspension was circulated to the top of the scrubber as wash liquid, and part flowed by free over-flow to a second tank, where oil and water separated. The scrubber-water was cooled partly indirectly

by a coil and partly directly by injection of cool water before the circulating pumps. From the separator the oil flowed to a third tank, where it was collected and measured. The water was pumped away, but could be measured intermittently in a container with known volume outside the tank. The separator and the collecting tank had coils for steaming at cold weather.

The condensate from the tube condensor flowed down to the second tank, (the separator).

Condensate of oil in the pipes after the tube condensor was drained <sup>and</sup> through a valve returned to the second tank.

The shale was transported to the retort-hopper by the belt-conveyor from a container in which the sacks had been emptied. Its volume was  $1,6 \text{ m}^3$  (~35 sacks). The shale was weighed by a band-scale, and the weight was checked by counting the sacks and evaluation of their net average weight. The spent shale was not weighed.

For the operation and control of the plant there were installed some orifice flowmeters, vacuum- and pressure gauges and thermometers (see drawing 13-199). All measurements and readings were manual. The retort temperature was measured at the points A and C outside the retort. The temperature of the circulated flue gases was measured at the burner inlet.

The injection of superheated steam was controlled by measuring temperature, pressure and amount (orifice). The amount of fuel gas was determined by an orifice meter, and the amount of uncondensable pyrolysis gas was measured by an orifice after the blower. The measure-points for temperatures and vacuum in the condensing system are shown in the flow sheet.

The amount of oil was measured in the third tank by measuring the depth of the oil layer after emptying the separating tank to a fixed level.

#### a) Sampling. Methods of analysis.

Raw shale: At every charging operation a sample of some kgs of shale was taken from the belt conveyor. The samples during a 24 hour-period were collected mixed, and divided. The following analysis are performed: Fischer assay (according to Fischer-Schrader), moisture content, elementary analysis on C, H (semi-micro, Reilen-Weinbrenner apparatus), S (Grothe-Krekeler and gravimetric determination of  $\text{SO}_4^{2-}$ ) and C as carbonate (HCl-treatment and measuring the volume of  $\text{CO}_2$ ), gross heat value (bomb-calorimeter) and ignition loss.

Spent shale(coke): At every discharge of the hopper some kilograms of coke were taken aside. The samples for a 24 hour-period were mixed and analyzed in the same respects as the raw shale. - Appreciation of the temperature of the coke was done by direct measurement in a pile of just discharged coke.

Shale Oil: After every test period a general sample was taken of the collected oil production in tank 3. The content of the tank was stirred before sampling.

Analysis (according to ASTM-standards): Spec. gravity (hydrometer), ASTM-distillation, water content (distillation with gasoline), pour point, elementary analysis of S, heat value (one sample). The viscosity was determined on two samples (Vogel - Ossag).

Water: Samples were occasionally taken out (no general samples were collected) and analyzed for  $\text{NH}_3$ - and oil content (extraction with ether).

Pyrolysis gas: Samples were taken at the orifices every second hour for determination of  $\text{CO}_2 + \text{H}_2\text{S}$  and  $\text{O}_2$  and every eight hour for complete Orsat-analysis and determination of the heat value (Junker-calorimeter). Twice the composition of the hydrocarbons was evaluated through distillations in Podbielniak apparatus.

Fuel gas: Determination of the heat value (Junker-calorimeter) was performed every eight hour, and complete Orsat-analysis twice.

Flue gases: Complete Orsat-analysis were done twice on samples taken after the recirculation blower.

c. The test runs. Operating data, results of analysis, yields, balances, operating experience.

The heating of the retort was started 44 hours before the beginning of the first test period. The following tests were made:

Test run nr.	Temp. at A °C	Steam admission kg/h	Duration of test hours hours
1	900	95	24
2	900	95	24
3	950	95	24
4	1000	95	24
5	950	55	24
6	950	85	72

All essential operating and production data are shown in tables 1-5 and graphically in fig. 1-2. Temperatures are average for 4-hour periods, and steam, shale oil and gas in- and output for 8-hour periods. Readings were done at least every hour. The results of the analyses are found in tables 6-11.

Operating.

The variations in steam temperature and pressure were small and the same is valid for the temperature of the circulated flue gases.

The raise of the water temperature in the scrubber was 1-2°C.

The vacuum in the retort (at the gas discharge pipe) was kept constant at 30 mm water, but the vacuum in the condensing system was higher, ~80 mm water, as the retort-vacuum for convenience was regulated with a valve immediately after the retort. The pressure drop through the whole condensing system was about 6 mm water.

The gas production reached much higher values than expected and the orifice in the gas pipe had to be changed. The first test was run, however, with the earlier, narrower orifice, which caused too high a pressure drop in the pipe and superpressure and gas leakage in the retort, which must be remembered when studying the gas yield in test hr. 1.

Because of small untightnesses in the condensing equipment a certain in-leakage of air was found, as seen from the analyses:

day	hour	immediately after the retort		after the condensing system	
		% $H_2S+CO_2$	% $O_2$	% $H_2S+CO_2$	% $O_2$
20.2.	11.00	46.2	0.2	39.7	2.2
	12.00	45.4	0.2	38.6	2.5
21.2.	04.10	31.1	4.1	24.7	6.0
22.2.	16.15	40.0	0.8	32.2	1.2

The oxygen contents of the gas immediately after the retort depended on air inleakage during the charging of the retort and small untightnesses in the retort wall. The extremely high value of 4.1 %  $O_2$  was caused by a temporarily blown-out water-seal.

All data on the pyrolysis gas have therefore been recalculated on air free basis. (No correction has been made for the part of air, which corresponds to oxygen, consumed in the hot retort zones. The recalculated gas analyses are thus not nitrogen-free.)

The variations in the temperatures A and C depended on occasional shortage of fuel gas, variations of its pressure and heat value etc. The hourly caloric input was calculated from heat values, determined every eight hour. Because of the variations in the gas composition the results must be regarded cautiously.

The two flue gas analyses made showed the presence of considerable amounts of combustible matter in spite of the large excess of air. Only about 80 % of the supplied fuel calories were thus utilized.

The shale throughput per eight-hour-shift was calculated from the number of sacks charged and their average net weight, determined by weighing 20 arbitrarily chosen sacks. The band scale registered a weight about 3 % too high and in the last 4 days even more.

The variations in the calculated throughputs depends partly on the difficulty of filling the retort to the same level every time, and partly on variations in the actual descending speed of the shale, due to small variations in the rotating rate of the discharge mechanisms.



gross sack weight, kg

51.0 52.1

50.2 47.6

49.7 49.4

49.0 50.7

53.0 53.9

49.5 50.7

50.7 49.2

50.6 50.4

53.4 48.5

51.8 50.2

aver. 50.55 kg (gross)

aver. 50.0 kg (net)

The greatest difficulty at the measurements of the oil amounts was to determine the level of oil-water interface in the second tank as it must be at the same place at start and end of the test. An emulsion of oil and water seemed to occur at the interface, causing inaccuracies, which are serious at so short test periods as 24 h.

Although the separation of oil and water in the second tank seemed to be good, it might not have been perfect. The water content of the oil was estimated on the oil sample from every test run, but the oil content of the water was determined only two times, arbitrarily chosen. They showed 0.7 and 2.5 g oil/ liter water, and as the amount of water is rather high (direct cooling!) usually ~300 l/h, the mentioned figures correspond to 5 resp. 18 kg oil/24 h.

### Analysis results.

Raw shale. The average oil yield according to Fischer, 9,8 % by weight, agrees well with the value reported as average from Rifle (Sampling and crushing report), 10,1 % (26,3 gal/ton).

Some analyses were later checked, namely Fischer-assay on shale from test run 5 and elementary analysis on shale from test run 6. The variations were considerable, and we can see no other reason for this than heterogeneous samples.

The coke from one Fischer test was analyzed for carbon and hydrogen whereby were found C = 7,31 and H = 0,18 % by weight. The spent shale from the HG-retort had a lower carbon content. The heat value of the spent shale from test run 3 seems to be too low with respect to its organic carbon content. As the accuracy of the heat value determinations is low at these low values, an average of 200 kcal/kg has been used for spent shale from all test runs in calorific balances.

The special sample from test run 6 consists of selected cemented pieces of spent shale. They contain, as expected, a higher percentage of organic material.

The discharged spent shale at the test runs was not weighed, but its weight can be estimated from ignition loss figures of raw and spent shale.

Test run	2	3	4	5	6
spent shale, % of raw shale	82,2	78,7	77,3	80,0	83,5

The degree of decomposition of the carbonates can be calculated from that estimation.

Test run	3	4	5	6
% decomposition of carbonates	40	58	44	13
% of organic C left in the spent shale	20	22	22	22

Shale oil. The oils from the different test runs were rather similar except the one from run 6, which had a higher API-gravity and a higher content of low-boiling constituents (more than 60 % distilled below 300°C).

Elementary analysis on oil from run 3: 84,6 % C, 12,04 % H and 1,5 % N.

The viscosity was determined at 100°F and 210°F for the oil of highest and lowest pour point (Table 8.).

The approximate wax content of these two oils was determined. 200 g oil was mixed with 500 ml acetone. The precipitated wax was 0,5 % by weight of the oil from test run 3, and 0,1 % of the oil from run 6.

A small refining test was made on gasoline ( $< 200^{\circ}\text{C}$ ) from the ASTM-distillation of oil from run 6 by treatment with NaOH-solution and subsequent treatment with "Doctor" solution. Total S-content decreased from 0,88 % by weight to 0,79 % and to 0,78 %. S as RSH decreased from 0,044 % by weight to 0,004 % and to 0,002 %.

#### Pyrolysis gas.

The results of the Orsat analyses and the heat value determinations, corrected to air free basis, are summarized in table 12 as averages over each test run.

Table 12.

Average composition and heat value of uncondensable pyrolysis gas.					
Test run	2	3	4	5	6
H <sub>2</sub> S, % by vol.	1,8	1,0	1,1	1,1	1,5
CO <sub>2</sub>	42,0	42,5	41,5	39,6	38,5
C <sub>n</sub> H <sub>2n</sub>	3,5	3,4	3,1	3,3	4,4
O <sub>2</sub>	-	-	-	-	-
CO	3,8	4,8	5,5	6,5	3,9
N <sub>2</sub>	6,1	5,6	4,0	4,7	5,1
H <sub>2</sub>	34,5	35,6	37,0	36,3	36,6
C <sub>n</sub> H <sub>2n+2</sub>	8,9	7,4	7,6	8,4	10,1
W <sub>net</sub> , kcal/Nm <sup>3</sup>	3150	2960	2830	2930	3190
W <sub>gross</sub> , "	3410	3320	3110	3200	3500

No tendency can be found in these figures. Lower temperature seems to give a gas with a little higher heat value, but the variations between the different samples (table 10) are too great to permit reliable conclusions.

Fuel gas and flue gas. The fuel gas was burned with considerable excess of air, the analyses indicating 50-60 %, which gives about 7 m<sup>3</sup> flue gas per m<sup>3</sup> fuel gas. The flue gas has  $c_p \sim 0,33 \text{ kcal/Nm}^3, ^{\circ}\text{C}$  in the range 25-250<sup>o</sup>C.

#### Yields, balances.

In Table 13 essential retorting and condensing data have been collected.

Table 13.  
Retorting, condensing and production data.

Test nr.	1-2	3	4	5	6
Durations, h	48	24	24	24	72
Temp. A, °C	890	940	1000	945	940
" C, °C	715	765	800	770	745
" of recirc. flue gas, °C	232	236	230	235	242
Steam admission, kg/h	94	95	94	53	73
" temp., °C	343	342	335	314	335
" pressure atm. (gauge)	0,33	0,33	0,31	0,05	0,20
Raw shale charged, ton/24 h	6,70	6,8	6,65	4,35	6,60
Fuel gas consumed, Nm <sup>3</sup> /h	33,5	36	41	35,5	34,5
- " heat value, gross, kcal/Nm <sup>3</sup>	4260	4440	4100	5000	4500
Fuel gas heat value, net, kcal/Nm <sup>3</sup>	3880	4020	3710	4200	4100
Gas temp. before scrubber, °C	94	93	90	85	89
" " after tube condenser °C	7	6	7	6	7
Crude oil produced, l/24 h	465	478	574	410	381
Crude gas " , Nm <sup>3</sup> /h	30,5	28,5	36,5	30	30
Water produced, l/h	~94	(120)	~93	~63	~93
Total water out, l/h	330	(390)	375	-	300
" " " , temp. °C	80	70	65	65	60
Crude oil, spec.grav.	0,902-0,895	0,899	0,890	0,893	0,873
" " gasoline content fr. <200°C	20	16	19	18	24
Crude oil, heat value, kcal/kg	10134	-	-	-	-
Crude gas, gross heat value kcal/Nm <sup>3</sup>	3390	3320	3110	3200	3500
Spent shale, heat value, kcal/kg	200				

Yield and calorific balance calculations are made in tables 14 and 15.

Table 14.

Yields (basis 1 metric ton raw shale)					
Test run	1-2	3	4	5	6
Crude oil, l/ton	69,5	71,5	86,5	94	58
" " , weight % of Fischer assay	62	64	82	88	53
Crude gas, Nm <sup>3</sup> /ton (air-free basis)	(112)	108	114	163	113
Spent shale, kg/ton (estimated)	820	790	775	800	835

Sensitive heat was fed to the system (retort and condenser) only as steam and was carried away as spent shale, flue gases and water (direct, indirect and pyrolysis water). The spent shale had a temp. of  $\sim 250^{\circ}\text{C}$  when leaving the hopper, and its specific heat may be  $0,25 \text{ kcal/kg}^{\circ}\text{C}$ . Thus about 50.000 kcal/ton raw shale was carried by the spent shale. The flue gases left with a temp. of  $\sim 235^{\circ}\text{C}$  and carried sensitive heat as steam (difference between gross and net heat values per Nm<sup>3</sup> fuel gas) and as specific heat ( $\sim 7 \times 0,33 \times 235/\text{Nm}^3 \text{ fuel gas}$ ). The heat content of pyrolysis and direct cooling water could be calculated from volume and temperature measurements (inlet temp. =  $10^{\circ}\text{C}$ ). The temperature raise and the amount of water used for indirect cooling was not known. Because of incomplete combustion in the burners it was supposed that 20 % of the fuel gas calories were not utilized.



Table 15.

Calorific balances (basis 1 metric ton raw shale)					
Calories input			Calories output		
Test run 1-2					
Raw shale	1270	$10^3$ kcal/ton = 63 %	Spent shale (x)		
Steam	220	" = 11 %	(50+160). $10^3$ kcal/ton = 11 %		
Fuel gas (gross)	510	" = 26 %	Crude oil	620	31 %
Total	2000	" = 100 %	Crude gas	380	19 %
			Water (xx)	90	5 %
			Flue gas	120+100	11 %
			Losses and not measured	480	24 %
			Total	2000	100 %
Test run 3					
Raw shale	1360.	$10^3$ kcal/ton = 64 %	Spent shale (50+160). $10^3$ kcal/ton = 10 %		
Steam	220	10 %	Crude oil	650	30
Fuel gas (gross)	560	26 %	Crude gas	360	17
Total	2140	100 %	Water	90-90	4
			Flue gas	120+110	11
			Losses and not measured	600	28
			Total	2140	100 %

x) = sensitive heat + heat value

xx) = water for direct cooling and pyrolysis water.

Test run 4.

Raw shale	1270.10 <sup>3</sup> kcal/ton = 61 %	Spent shale (50+160).10 <sup>3</sup> kcal/ton = 10 %
Steam	220 10	Crude oil 770 37
Fuel gas(gross)	610 29	Crude gas 350 17
Total	2100 100 %	Water <del>80</del> 80 4
		Flue gas 140+120 12
		Losses and not measured 430 20
		Total 2100 100 %

Test run 5

Raw shale	1380.10 <sup>3</sup> kcal/ton = 56 %	Spent shale (50+160).10 <sup>3</sup> kcal/ton = 8 %
Steam	210 8	Crude oil 840 39
Fuel gas(gross)	910 36	Crude gas 520 21
Total	2500 100 %	Water <del>20</del> 20 1
		Flue gas 240+180 17
		Losses and not measured 510 20
		Total 2500 100 %

Test run 6

Raw shale	1270.10 <sup>3</sup> kcal/ton = 62 %	Spent shale (50+170).10 <sup>3</sup> kcal/ton = 11 %
Steam	200 10	Crude oil 510 25
Fuel gas(gross)	570 28	Crude gas 400 20
Total	2040 100 %	Water <del>60</del> 60 3
		Flue gas 120+110 11
		Losses and not measured 620 30
		Total 2040 100 %

The amount of heat required to decompose the carbonates ( $MgCO_3$  and  $CaCO_3$ ) is about 50.000 kcal/ton raw shale at 40 % decomposition.



Material balances have been calculated for carbon and sulphur.

### Carbon-balances.

Test nr	kg C per metric ton raw shale.				
	2	3	4	5	6
<u>IN:</u> Raw shale:					
organic C	173	129	128	131	132
carbonate C		42	43	44	43
	173	171	171	175	175
<u>OUT:</u> Spent shale:					
organic C	62	26	29	28	30
carbonate C		25	17	24	34
Oil:	53	54	65	71	43
Gas:					
organic C	16	17	18	29	22
carbonate C	26	25	26	35	23
Water:					
carbonate C	-	-	-	-	-
(no analyses)					
	157	147	155	187	152
Diff.	16	24	16	-12	23

### Sulphur-balances.

Test nr	kg S per metric ton raw shale.				
	2	3	4	5	6
<u>IN:</u> Raw shale	6,4	6,9	5,9	7,3	5,8
<u>OUT:</u> Spent shale	2,8	2,7	3,3	2,6	2,8
Oil	0,7	0,6	0,7	0,7	0,5
Gas	3,1	1,6	1,8	2,6	2,5
Water	-	-	-	-	-
(no analyses)					
	6,6	4,9	5,8	5,9	5,8
Diff.	-0,2	2,0	0,1	1,4	0

The yields show a tendency for higher yields of oil at higher temperatures. The temperature of the shale in the retort has supposedly been highest in test run 5 (depending on a 50 % longer retorting time) and lowest in run 6 (short warming-up period before the test period). Some accumulation of oil in the feed hopper may have contributed to the very low yield in test run 6 (inspection afterwards revealed oil in the hopper).

Inaccuracy in production data and sampling for the too short test periods and pre-periods with relatively small changes in retorting conditions may lead to false conclusions, and therefore we think it is more decent to calculate the over-all yield for all test periods. Thus for test periods 1-4 and 6 (together 7

Retorting: 6.65 ton/24 h at temp. A ~935° and C ~745°C  
Yields: Oil 67.5 lit/ton shale (Sp.gr. 0.885-90; 21 % <200°C)

corresp. to 61 % of Fischer assay

Gas 112 Nm<sup>3</sup>/ton shale with gross heat value ~3400 kcal/Nm<sup>3</sup>

The figure for yield will be increased by 4-5 % if including recoverable light gasoline from the gas.

The yield is low compared to that obtained at retorting Swedish shale. This can, however, be fully explained by regarding the lower retorting temperature and the size of the shale.

Operating experience from the whole plant (supported by calculations of heat transfer in beds of different particle sizes) shows that the rate of pyrolysis is less the smaller the shale pieces are. Of course this is counteracted by the 50 % longer pyrolysis time.

The calorific balances show that about the same amount of calories introduced with the raw shale came out as oil, gas and spent shale. There is a small difference between runs at high and low temperature, but temperature definitions were too inaccurate, and the calories not accounted for too many to permit any conclusions.

In none of the test runs the calories of the pyrolysis gas was enough to supply the heat necessary for heating the retort.

The retort system is thus not self-sustaining in calorific respect when retorting Green River oil shale.

Improvements in burner design and heat transfer surfaces may diminish the gap between consumed and produced gas-calories, and utilization of part of the calories in spent shale and flue gases may be possible. This would, however, require additional research to get the retort system to fit better for an oil shale of Green River-type.

It is quite clear that retorting Green River shale in the HG-retort gives an easily condensable oil with much higher API-gravity and a considerably higher amount of gasoline than oil produced in retorts to which the heat is transferred directly to its interior by gases, and the pyrolysis gas has a good heat value and contains recoverable light hydrocarbons.

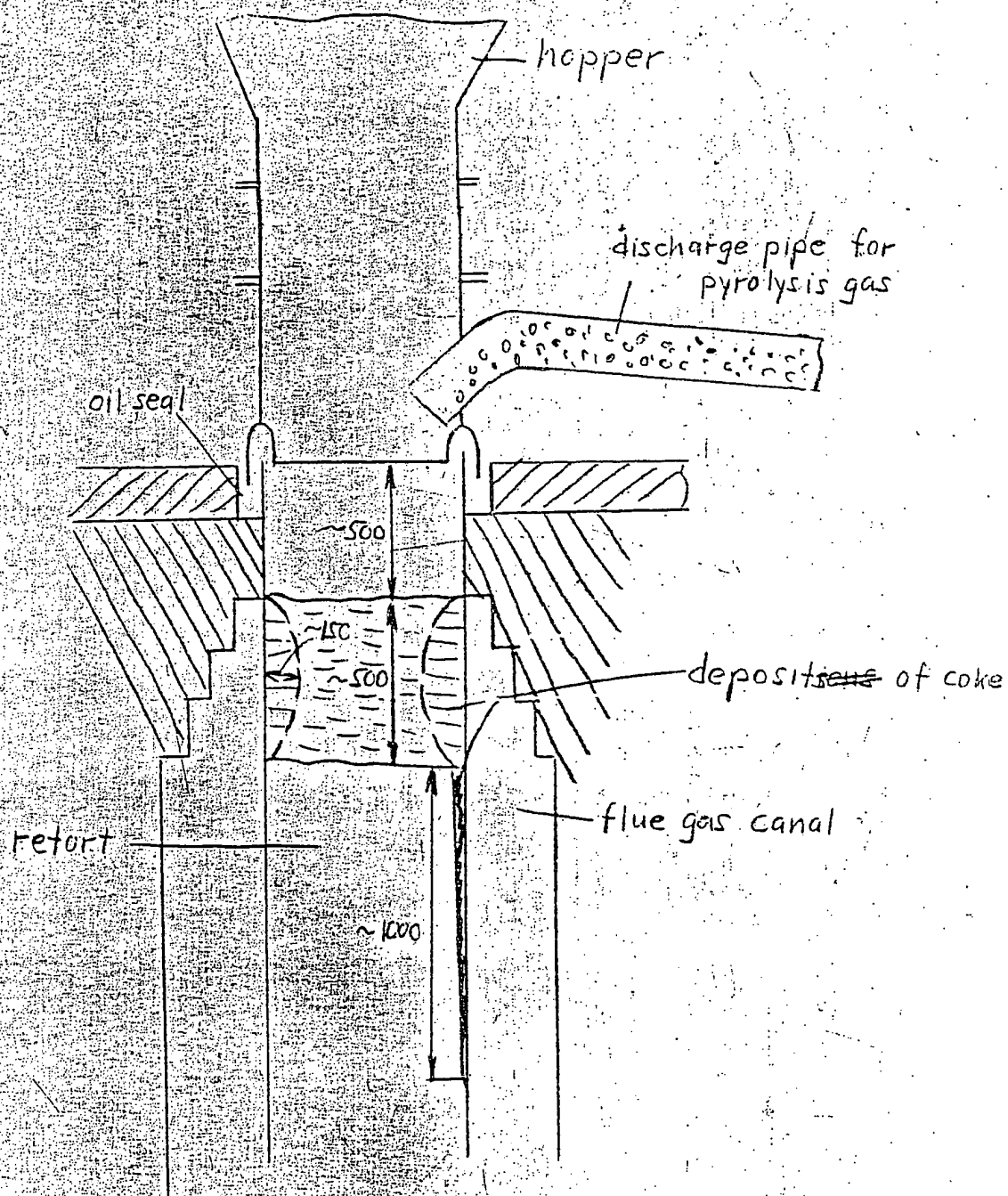


Fig. 5 Deposits in the retort after the tests.

#### Operating experience.

The operating of the retort with Green River shale caused some troubles. After 6 days on line the throughput decreased. Lumps of cemented shale pieces appeared at the discharge mechanism. This occurred when the steam input had been decreased, but it is questionable if that was the cause. A gradually building-up on the walls at the top of retort and loosening later seems equally probable. Small cemented lumps could be observed during all test runs. The lumps finally stopped the discharging at the narrow openings. After the big lumps had been taken away the throughput was normal again.

Inspection of the retort revealed that deposits had been formed at the top of the retort proper (see fig.), and pieces of shale had been carried with the gas stream into the gas discharge tube, which was nearly filled with shale and oil to the first valve. This would probably not have occurred with bigger shale pieces. The deposits were probably formed by dust and condensed oil or oil that occasionally was sucked in from the oil-seal. The dust and oil coked to hard deposits including shale pieces on the hot retort-wall where the canal for the combustion gases ends. The raw shale contained some dust, and much dust was formed in the retort, which could be observed in the discharged material. It seems probably that these troubles would not occur if a bigger particle size of shale is used. It can be mentioned that deposits have been observed in retorts with Swedish shale which have been in service for many years.

The top of the retort and the hopper became warmer than by retorting Swedish shale, causing the water seal to run dry rather frequently.

The condensing equipment functioned well except for some cloggings of the pipes, as the weather was cold frequently, below 0°C, and the oil has high pour point.

#### 4. Summary of the test runs.

Green River oil shale of size 12-32 mm (minus 1 1/4" plus 1/2") has been retorted in a HG-retort with a throughput of 6,7 tons/24 h (about 11 tons is normal for Swedish shale of size 27-70 mm) and at temperatures somewhat lower than for Swedish shale. The conditions were altered a little through 6 test runs.

The oil yield varied from 53 to 88 percent of Fischer assay. These yields are increased with about 4 % if the recoverable light gasoline from the gas is included. The spec. gravity of the oil was 0,873-0,902, and its gasoline-content (<200°C) 16-24 % by vol.

Uncondensable pyrolysis gas was produced to an amount of 108-163 Nm<sup>3</sup>/ton raw shale and with a gross heat value of 3100-3500 kcal/Nm<sup>3</sup> (incl. light gasoline).

Calorific balances show that the retort is not self-sustaining with Green River shale, i.e. it consumes more fuel gas calories than it produces as uncondensable pyrolysis gas.

It is believed that the size of the Green River shale is largely responsible for the low yields and operating troubles. Operating experience with Swedish shale indicates that better yields and less operating troubles may be obtained with bigger sizes of the shale, although only new test runs can give definite answer. There is, however, not much hope that the retort system can become thermally self-sustaining with Green River shale.

Närkes Kvarntorp den 17.5.52.

SVENSKA SKIFFEROLJE A.B.

Laboratoriet

*B. Skjerveberg*  
*G. Salomonson* *Ake Brandberg*



Table 1.

Raw shale input (Calc. on basis of 8 hour periods).

Date	Shift	kg shale/h	Date	Shift	kg shale/h
Febr. 17	I	267	23	I	146
	II	301		II	256
	III	352		III	187
18	I	289	24	I	135
	II	265		II	48
	III	278		III	-
19	I	203	26	II	244
	II	256		III	271
	III	276		I	249
20	I	267	27	II	228
	II	318		III	292
	III	312		I	365
21	I	307	28	II	242
	II	335		III	289
	III	281		I	280
22	I	196	29	II	212
	II	174		III	250
	III	182			

Shift I 07-15

II 15-23

III 23-07

Table 2.  
Steam input.

Data	Shift	kg steam/h	Temp. °C	Pressure(gage) atm	kg steam/ ton shale
Febr. 16	I-III	92	338	0,34	
17	I-III	93	342	0,33	303
18	I-III	94	346	0,32	339
19	I	98	330	0,33	483
	II-III	95	343	0,33	
20	I		339	0,32	360
	II		336	0,33	280
	III	94	330	0,30	
21	I-II		338	0,31	295
	III	53	311	0,05	170
22	I-II	53	314	0,05	287
	III	73	335	0,20	400
23	I	83	339	0,25	590
	II	99	346	0,20	385
	III	99	349	0,20	530
24	I	84	347	0,13	620
	II	81	343	0,13	1700
26	II	82	347	0,1	336
	III	82	350	0,1	302
27	I	83	345	0,1	333
	II	82	349	0,1	360
	III	87	351	0,1	298
28	I	84	348	0,1	230
	II	82	344	0,1	338
	III	87	345	0,15	300
29	I	82	344	0,1	292
	II	81	342	0,1	382
	III	85	329	0,1	340

Table 3.

## Fuel gas input.

(calculated for  $\gamma_{0,760} = 0,92 \text{ kg/m}^3$ )

Date	Shift	$\text{Nm}^3/\text{h}$	Average heat value(gross) $\text{kcal/Nm}^3$	Average calorific input, $\text{kcal/h}$
Febr. 16	I	36,0	4450	158.000
	II	34,4		
	III	36,7		
17	I	33,6	4310	143.000
	II	32,0		
	III	33,6		
18	I	32,0	4210	143.000
	II	36,0		
	III	33,6		
19	I	35,2	4440	160.000
	II	36,0		
	III	34,8		
20	I	37,4	4100	169.000
	II	44,1		
	III	42,2		
21	I	43,4	5000	177.000
	II	38,1		
	III	36,7		
22	I	37,4	5000	177.000
	II	32,0		
	III	36,7		
23	I 07-10	36,6	4530	150.000
	10-16	0		
	II 16-22	34,4		
	III	28,0		
24	I	32,8	4530	150.000
	II	30,5		
	II 23-02	22		
	02	0		
26	I 11-14	48,7	4600	160.000
	II	37,4		
	III	38,8		
27	I	32,8	4530	150.000
	II	34,8		
	III	32,0		
28	I	32,0	4600	160.000
	II	35,2		
	III	37,4		
29	I	34,4	4360	
	II	36,0		
	III	37,4		
March 1	I 07-16	35,2		



Table 4.

## Oil production.

Date	Tim	liters of oil	liters/h
Febr. 17	05.00	0	
	12.30	122	16,3
	23.30	294	15,6
18	12.00	591	23,8
	19.00	739	21,2
	02.30	907	22,4
19	11.00	1047	16,5
	15.50	x)	-
	01.25	1174	
20	08.00	1338	24,0
	15.25	1516	24,0
	23.30	x)	-
21	04.45	1651	
	16.00	1868	19,3
	23.40	2093	29,3
22	06.30	2193	14,6
	01.45	2490	16,0
	06.30	2603	23,8
	03.00	2848	10,9
	21.25	3054	11,2

x) An amount pumped off unmeasured.

Table 4. (cont. d)

Date	Time	liters of oil	liters/h
Febr. 26	11.55	153	
27	04.00	377	13,9
	08.20	452	17,3
	19	642	19,0
28	04.20	804	17,4
	07.55	888	23,5
	20.00	1082	16,1
29	08.20	1228	11,8
	18.00	1483	16,0
March 1	08.05	1693	14,9

Oil production during the test runs.

Test nr.	Period	oil, lit/24 h	lit.oil/ton shale
1	17/2 07-18/2 07	} 465	} 69,5
2	18/2 07-19/2 07		
3	19/2 16-20/2 16	478	71,5
4	20/2 23-21/2 23	574	86,5
5	22/2 07-23/2 07	410	94
6	27/2 08-1/3 08	381	58

Table 5.

## Production of pyrolysis gas.

(The amount of gas is calculated with  $\gamma_{0,760} = 1,15 \text{ kg/m}^3$ )

Date	Shift	Crude gas Nm <sup>3</sup> /h	% O <sub>2</sub>	Crude gas (air-free ba- sis) Nm <sup>3</sup> /h	Nm <sup>3</sup> /ton raw shale
Febr. 17	I	(22,8)	2,5	(20,0	75)
	II	(24,7)	1,7	(22,6	75)
	III	(21,7)	1,8	(19,7	56)
18	I	(22,2)	1,7	(20,3	70)
	II	49,0	7,6	30,4	115 New ori- fice
	III	30,9	1,7	30,3	109
19	I	32,8	1,9	29,6	146
	II	34,3	1,7	31,4	125
	III	30,9	2,1	27,4	100
20	I	29,9	2,4	26,3	99
	II	37,9	2,0	34,1	107
	III	46,8	5,1	34,8	111
21	I	42,3	3,3	35,3	115
	II	41,1	1,1	38,8	116
	III	50,2	6,8	33,2	118
22	I	31,5	2,5	27,6	141
	II	32,8	1,3	30,6	176
	III	{ 32,9 47,2	{ 1,6 6,5	{ 30,3 31,8	172
23	I	24,3	2,3	21,5	154
	II	{ 18,0 25,6	{ 2,6 2,5	{ 15,5 22,4	135
	III	21,4	3,7	17,5	94
24	I	27,4	2,6	23,8	176
	II	25,0	2,7	21,6	450
	III	16,4	3,7	13,4	

Date	Shift	Crude gas		Crude gas (air-fri, ba- sis) Nm <sup>3</sup> /h	Nm <sup>3</sup> /ton raw shale
		Nm <sup>3</sup> /h	% O <sub>2</sub>		
Febr. 26	I	17	4,7	13	
	II	18,2	3,7	14,8	
		40,5	10,3	20,1	74
		21,7	2,2	19,3	
	III	31,8	1,7	29,0	107
	I	31,2	2,4	27,5	110
27	II	29,2	1,8	26,6	107
	III	35,2	1,6	32,4	111
	I	32,0	1,6	29,4	81
28	II	32,1	1,5	29,7	123
	III	34,0	1,6	31,3	108
	I	38,4	2,3	34,0	121
29	II	32,9	2,0	29,6	140
	III	31,5	1,6	29,0	116
March 1	I	31,0	1,2	29,1	



Table 6.

Analysis of raw shale.

Test run nr.	0	1	2	3	4	5	6
Date	16/2 - 17/2	17/2 - 18/2	18/2 - 19/2	19/2 - 20/2	20/2 - 21/2	22/2 - 23/2	27/2 - 1/3
Time	07 07	07 07	07 07	16 16	23 30 23 30	06 30 06 30	08 08
Fischer assay:							
oil, % by weight	9,7	9,7	10,5	10,0	9,4	9,5 <sup>x</sup>	9,6
coke, "	85,8	86,8	85,6	86,9	87,4	87,4 <sup>x</sup>	87,3
H <sub>2</sub> O, "	1,6	1,8	1,9	1,5	1,6	1,6 <sup>x</sup>	1,9
Moisture "	0,2	0,3	0,2	0,2	0,1	0,2	0,3
Total C, % "	-	16,3	17,3	17,08	17,07	17,52	17,5
carbonate C, % "	-	-	-	4,21	4,29	4,35	4,30
H <sub>2</sub> , % "	-	1,62	1,77	1,77	1,69	1,83	2,11
Si, % "	-	0,63	0,64	0,69	0,59	0,73	1,78
Gross heat value, kcal/kg	-	1200	1310	1360	1270	1385	1265

1) Average of

9,2 87,3 1,9  
 9,8 87,1 1,4  
 9,5 87,4 1,3  
 9,2 87,3 1,9  
 9,7 87,8 1,3

Table 7.  
Analysis of spent shale.

Test run nr.	0	1	2	3	4	5	6	spec. sample
Date	16/2 - 17/2 07	17/2 - 18/2 07	18/2 - 19/2 07	19/2 - 20/2 16	20/2 - 21/2 23.30	22/2 - 23/2 06.30	27/2 - 1/3 08	
Time	07	07	07	16	23.30	06.30	08	
Fischer assay:								
oil % by weight	0,0	-	-	0,0	0,05	0,05	0,05	
coke %	99,7	99,5	99,1	99,5	99,5	99,45	99,3	99
H <sub>2</sub> O %	0,0	0,5	0,8	0,5	0,5	0,5	0,7	
Moisture, %	-	-	-	-	-	-	-	
Ignition loss, % by w.	-	-	18,5	15,8	13,0	16,3	18,0	21,
total C, % by weight	-	7,5	7,5	6,45	5,95	6,62	7,66	10,
Carbonate C, %	-	-	-	13,16	12,26	3,06	4,12	
" H <sub>2</sub> SO <sub>4</sub>	-	0,41	0,31	0,23	0,27	0,25	0,26	0,
" S	-	0,40	0,34	0,34	0,43	0,33	0,33	0,
Gross heat value kcal/kg	0,28	225	165	(35)	190	210	210	(27)

Table 8.

Analysis of shale oil.

Test run nr.	0	1	2	3	4	5	6
Date,	16/2 - 17/2	17/2 - 18/2	18/2 - 19/2	19/2 - 20/2	20/2 - 21/2	22/2 - 23/2	27/2 - 1/3
Time	07 07	07 07	07 07	16 16	23.30 23.30	06.30 06.30	08 08
Sp.gr. at 20°C	0,889	0,902	0,895	0,899	890	0,893	0,873
" °API	27,7	25,4	26,6	25,5	27,5	27,0	30,6
ASTM-dist.f.d. °C	60	49	58	72	48	57	72
5 %, °C	146	149	140	144	146	149	143
10 %, °C	163	167	163	181	167	169	161
20 %, °C	197	200	200	218	206	211	191
30 %, °C	231	237	231	256	241	246	220
40 %, °C	-	274	258	278	266	275	40% 247 50% 272 60% 297
Overdist. at 200°C	21	20	20	16	19	18	24
" (392°F)	-	49	48	46	54	49	61
" at 300°C	-	0,1	0,1	6,4	1,2	0,5	0,3
" (572°F)	0,6	+10(50)	+8(46)	+14(57)	+12(54)	+5(41)	+4(39)
H <sub>2</sub> O, %	-	-	-	-	-	-	-
Pour point, °C(°F)	+12(54)	-	10134	-	-	-	-
Gross heat value	-	-	1,08	0,88	0,91	0,88	0,94
kcal/kg	-	-	-	6,3	-	-	3,24
S, % by weight (gravim)	-	-	-	2,00	-	-	1,22
Viscosity at 100°F cSt	-	-	-	-	-	-	-
2100°F cSt	-	-	-	-	-	-	-



Table 9.

## Analysis of pyrolysis gas.

Test run nr.	0			1			2		
	Date	Time		Date	Time		Date	Time	
net $W_1$ , kcal/nm <sup>3</sup>	16.2.	18.00	01.00 x	17.2.	10.45	17.00	18.2.	11.15	16.30
gross $W_u$ , "	09.30	16.00 x		2030	2350	2650	2980	1830	2380
				2200	2600	2900	3260	1980	2560
H <sub>2</sub> S, % by vol.	1.4	0.0	1.0	1.4	1.6	1.6	2.1	0.9	1.3
CO <sub>2</sub>	34.2	30.8	33.8	35.0	40.0	35.2	38.7	21.5	38.7
C <sub>n</sub> H <sub>2n</sub>	2.8	1.8	6.4	3.2	3.2	3.4	3.6	2.0	2.1
O <sub>2</sub>	3.2	4.8	1.6	2.0	1.2	3.2	1.0	10.4	2.4
CO	3.2	2.8	4.2	2.8	4.0	2.8	3.4	1.6	4.1
N <sub>2</sub>	22.9	27.2	23.5	17.0	8.6	17.1	9.4	40.0	16.5
H <sub>2</sub>	24.8	26.4	25.6	31.0	32.4	29.0	32.6	18.0	29.6
C <sub>n</sub> H <sub>2n+2</sub>	37.5	6.2	5.7	7.6	9.0	7.7	9.2	5.6	5.3

x) Aspirator used.

Table 2. (cont. "d)

Analysis of pyrolysis gas.

Test run nr.	3		4		5	
Date	19.2.	20.2.	21.2.		22.2.	
Time	17.15	00.30 x)	01.30 11.45 14.30 16.30		11.00 16.45 00.00 x)	
net $W_1$ , kcal/Nm <sup>3</sup>	2800	2520	2750		2780	2380
gross $W_u$ , "	3040	2780	3010		2950	2610
H <sub>2</sub> S, % by vol.	1.1	0.2	0.4	1.9	1.2	0.7
CO <sub>2</sub>	38.3	39.8	38.8	38.7	34.4	39.5
C <sub>n</sub> H <sub>2n</sub>	3.0	3.0	3.4	3.0	3.6	2.0
O <sub>2</sub>	1.6	1.4	2.0	1.8	1.6	1.9
CO	4.0	5.0	4.0	4.6	7.4	5.1
N <sub>2</sub>	15.0	10.4	9.8	11.0	10.0	10.9
H <sub>2</sub>	32.4	32.4	33.2	32.6	33.2	34.2
C <sub>n</sub> H <sub>2n+2</sub>	4.6	7.8	8.4	6.4	8.6	5.7

x) Aspirator used.

Table 2. (cont. "d)

Analysis of pyrolysis gas.

Test run nr.	24.2.	25.2.	27.2.	28.2.	29.2.
Date	06.00	17.00 x)	17.15	16.30	17.00
Time	06.00	01.30 x)	23.15	18.00	11.15
net $W_1$ , kcal/Nm <sup>3</sup>	2060	1330	2770	3230	2820
Gross $W_u$ , "	2270	1500	3100	3490	3100
H <sub>2</sub> , % by vol.	0,9	0,6	1,1	1,4	1,3
CO <sub>2</sub>	39,7	42,2	33,9	36,8	31,1
C <sub>n</sub> H <sub>2n</sub>	1,4	1,8	4,4	4,0	3,4
O <sub>2</sub>	3,2	1,6	1,8	1,6	1,4
CO	2,2	2,8	4,0	3,6	2,6
N <sub>2</sub>	21,0	12,2	11,8	9,4	18,0
H <sub>2</sub>	27,2	32,4	31,8	33,4	31,2
C <sub>n</sub> H <sub>2n+2</sub>	4,4	6,4	11,2	9,8	8,4

x) Aspirator used.

Table 9 a.

Podbielniak distillations of hydrocarbons in uncondensable pyrolysis gas. % by volume of total gas (air-free basis).

	Time for sampling	
	21.2. 14.30	26.2. 18.00
H <sub>2</sub> S+CO <sub>2</sub>	40,4	38,0
Inert	48,9	49,6
CH <sub>4</sub>	5,9	6,8
C <sub>2</sub> H <sub>4</sub>	2,3	1,3
C <sub>2</sub> H <sub>6</sub>		1,7
C <sub>3</sub> H <sub>6</sub>	1,3	1,4
C <sub>3</sub> H <sub>8</sub>		0,4
i-C <sub>4</sub>	0,8	0,2
other C <sub>4</sub>		0,8
C <sub>5+</sub>	0,5	0,4



Table 10.

Analysis of pyrolysis gas.  
(calculated to air-free basis)

Test run nr.	0		1		2	
Date	16.2.		17.2.		18.2.	
Time	09.30	16.00	10.45	17.00	11.15	16.30
		01.00		01.00		00.30
net $W_1$ , kcal/Nm <sup>3</sup>		2550		3370		3330
gross $W_u$ , "		2820		3680		3650
$H_2S$ , % by vol.	1,7	-	1,5	1,7	2,2	1,5
$CO_2$	40,3	39,9	38,7	42,5	40,7	43,6
$C_nH_{2n}$	3,3	2,3	3,5	3,4	3,8	2,4
$O_2$	-	-	-	-	-	-
$CO$	3,8	3,6	3,1	4,3	3,6	4,6
$N_2$	12,9	11,9	10,5	4,3	5,9	8,5
$H_2$	29,2	34,2	34,2	34,5	34,3	33,4
$C_nH_{2n+2}$	8,9	8,0	8,4	9,6	9,7	6,0
						11,5

x) Aspirator used.

Table 10. (cont.'d)

Analysis of pyrolysis gas.

(calculated to air-free basis)

Test run nr.	3			4			5
Date	19.2.	20.2.		21.2.			22.2.
Time	17.15	00.30 x)	10.30 x)	01.30	11.45	14.30	01.30
			16.00			16.00	11.00
net $W_1$ , kcal/Nm <sup>3</sup>	3040	2710	3060	3020	2700	2790	3020
gross $W_u$ , "	3300	2990	3360	3300	2990	3010	3210
H <sub>2</sub> S, % by vol.	1.2	0.2	0.4	2.1	1.0	1.2	1.3
CO <sub>2</sub>	41.5	42.9	43.2	42.5	40.0	43.5	37.2
CH <sub>4</sub>	3.3	3.2	3.8	3.3	3.3	2.9	3.9
O <sub>2</sub>	-	-	-	-	-	-	-
CO	4.3	5.4	4.4	5.0	6.3	5.4	8.0
N <sub>2</sub>	9.7	5.5	2.5	4.6	1.9	2.1	3.3
H <sub>2</sub>	35.1	34.8	36.7	35.8	34.8	39.6	36.0
CH <sub>4</sub> n <sub>2</sub> +2	5.0	8.4	9.2	7.0	8.6	5.8	9.4

x) Aspirator used.

Table 10. (cont. 'd)

Analysis of pyrolysis gas.

(calculated to air-free basis)

Test run nr.	5				
Date	22.2	24.2	25.2		
Time	16.45	06.00	17.00 <sup>x)</sup>	01.30 <sup>x)</sup>	
net $W_1$ , kcal/Nm <sup>3</sup>	3140	2620	2240	1610	
gross $W_u$ , "	3520	2870	2470	1810	
H <sub>2</sub> S, % by vol.	1,1	0,8	1,1	1,0	
CO <sub>2</sub>	38,3	43,4	46,0	43,6	
C <sub>n</sub> H <sub>2n</sub>	3,7	2,2	2,0	1,0	
O <sub>2</sub>	-	-	-	-	
CO	6,0	5,6	3,0	1,7	
N <sub>2</sub>	6,8	4,1	6,7	13,5	
H <sub>2</sub>	35,3	37,6	32,1	34,8	
C <sub>n</sub> H <sub>2n+2</sub>	9,5	6,3	5,2	4,5	

x) Aspirator used.



Table 10. (cont. d)

Analysis of pyrolysis gas.  
(calculated to air-free basis)

Test run nr. Date Time	6											
	27.2	17.15	23.15	08.30	16.30	18.00	23.30	11.15	17.00	24.00	29.20	
net W, kcal/Nm <sup>3</sup>	2750	3020	3040	3080	3510		3270	3120	3480	3390		
Gross W, "	3020	3340	3400	3350	3800		3570	3470	3830	3780		
H <sub>2</sub> S, % by vol.	1.2	1.1	1.2	2.2	1.5		1.5	1.9	1.6	1.5		
CO <sub>2</sub>	41.4	38.0	37.2	37.2	40.0	38.4	38.7	36.0	38.4	39.7		
C <sub>2</sub> H <sub>2</sub> n	3.8	3.6	4.8	4.6	4.3	4.5	4.9	4.4	4.2	4.5		
O <sub>2</sub>	-	3.0	-	-	-	-	-	-	-	-		
CO	4.4	4.0	4.4	4.3	3.9	3.5	3.7	3.7	3.2	4.1		
N <sub>2</sub>	3.5	9.4	5.5	8.0	3.7	8.4	2.1	7.2	3.6	3.2		
H <sub>2</sub>	35.1	35.4	35.1	35.0	36.3	36.6	39.4	36.5	38.5	37.8		
C <sub>2</sub> H <sub>4</sub> n	10.6	8.6	12.3	9.2	10.7	8.7	10.0	10.8	10.4	9.5		

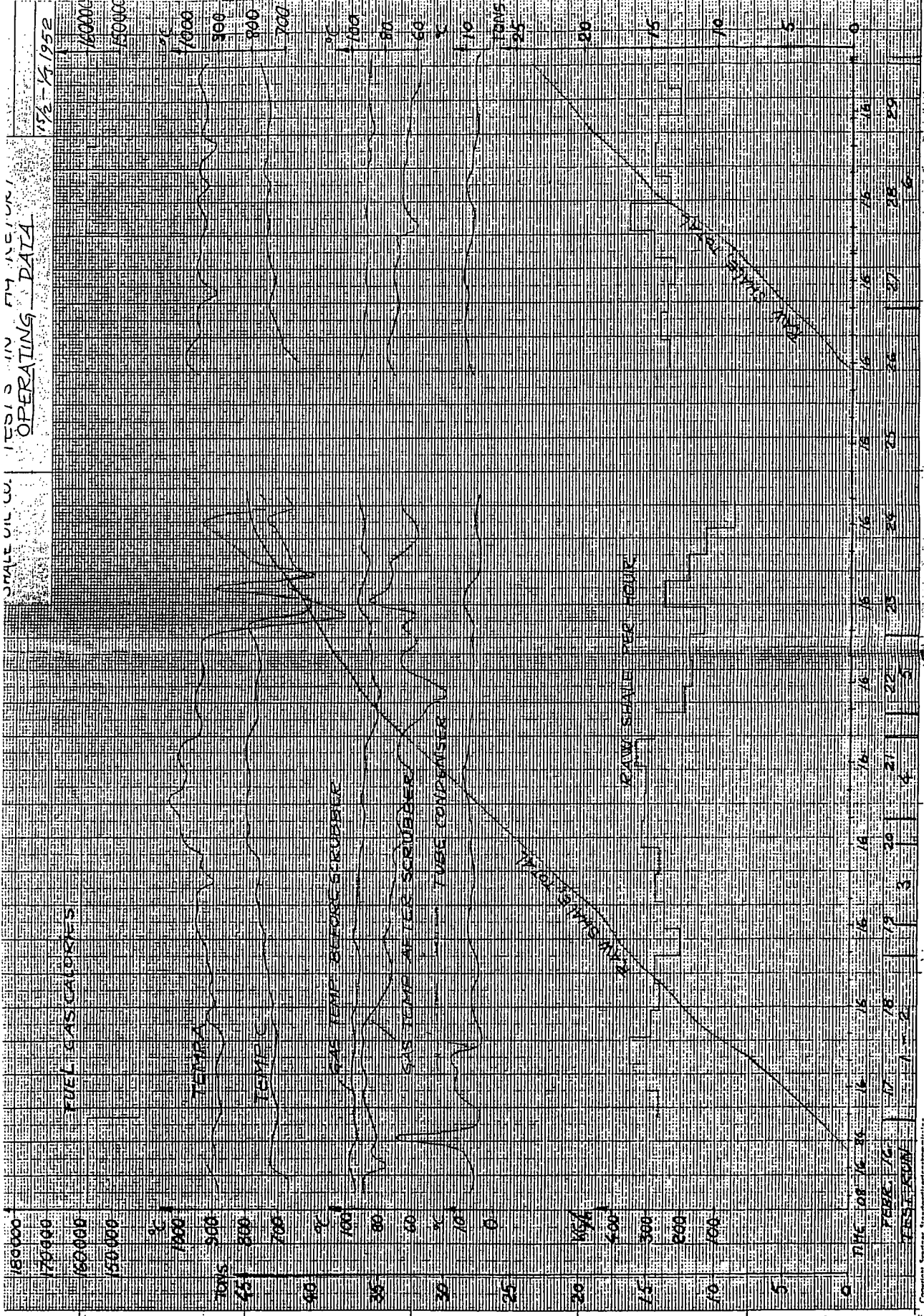
Table 11.

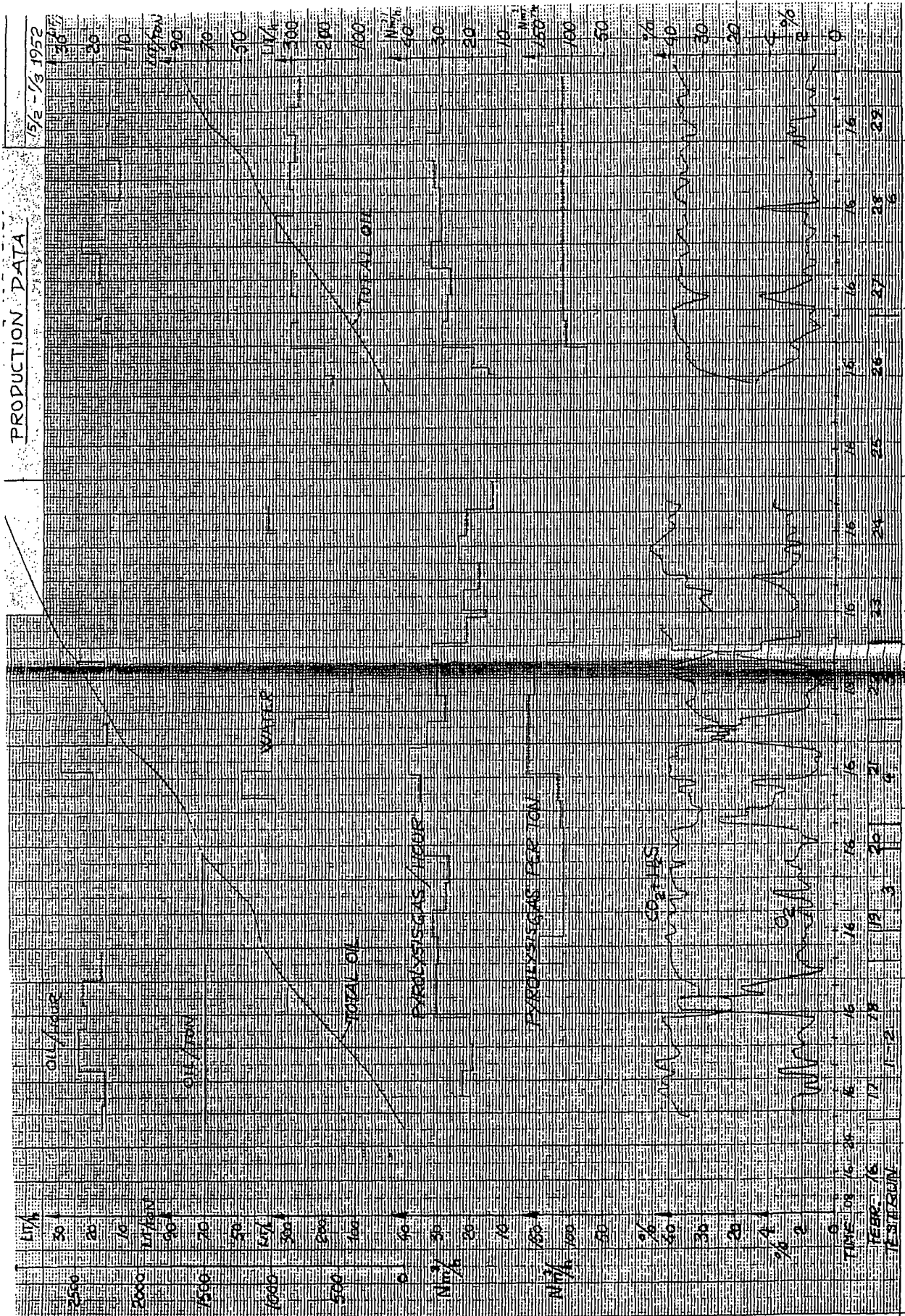
Analysis of fuel gas.

Test run nr.	0	1	2	3
Date	15.2.	17.2.	18.2.	19.2.
Time	14.00	09.45	10.00	10.30
	08.50	18.00	17.00	16.30
net W, kcal/Nm <sup>3</sup>	4150	3920	3800	4140
" " " " " "	4150	4040	3740	4160
gross W, kcal/Nm <sup>3</sup>	4630	4360	4170	4640
" " " " " "	4630	4360	4170	4640
H <sub>2</sub> +CO <sub>2</sub> , % by vol.	4.0	3.9	4.70	5.20
C <sub>n</sub> H <sub>2n</sub>	2.4	2.5		
O <sub>2</sub>	1.0	1.0		
CO	2.6	2.4		
H <sub>2</sub>	23.6	19.6		
N <sub>2</sub>	40.1	38.1		
C <sub>n</sub> H <sub>2n+2</sub>	26.3	22.3		









SIS 523 A 3  
 1 x 1 mm  
 4447

SHALE OIL CO.

# TESTS IN 179-RETURN ASTM-DISTILLATION OF OILS

5

3 - 20/2  
19/2 - 16.00

2 - 19/2  
19/2 - 07.00

1 - 18/2  
17/2 - 07.00

TEST RUN

°C °F

300-572

50

200-392

50

00

50

0 10 20 30 40 50% by vol

0 10 20 30 40 50%

0 10 20 30 40 50%



SHALE OIL CO. TESTS IN HG-RETORT  
ASTM-DISTILLATION OF OILS

25

6  
27 1/2 - 1/8  
08 1/2 - 08 1/2

5  
27 1/2 - 23 1/2  
06 30 - 06 10

4  
29 1/2 - 31 1/2  
23 30 - 23 30

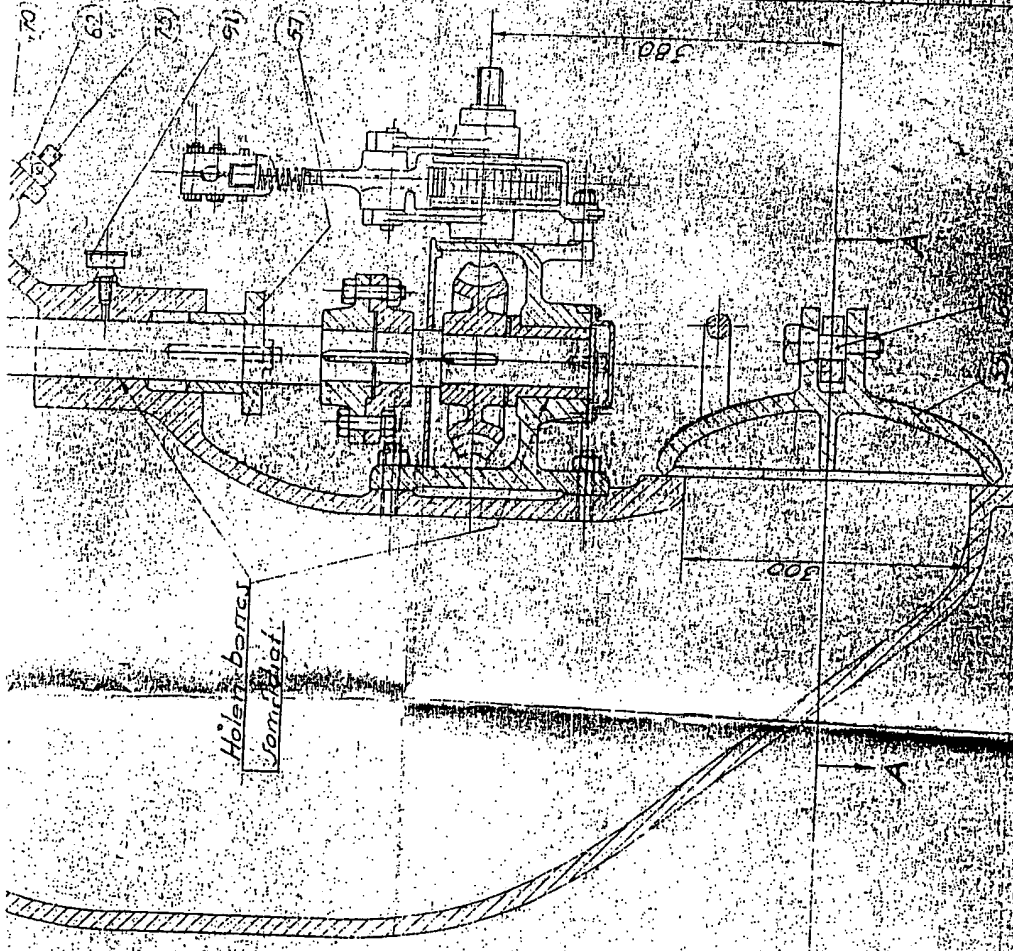
EST RUN

00-572  
C 10 F

00-398

10 20 30 40 50 %  
10 20 30 40 50 %  
10 20 30 40 50 %





Hölen bærer  
sommer

Materialförteckning för en undersökning

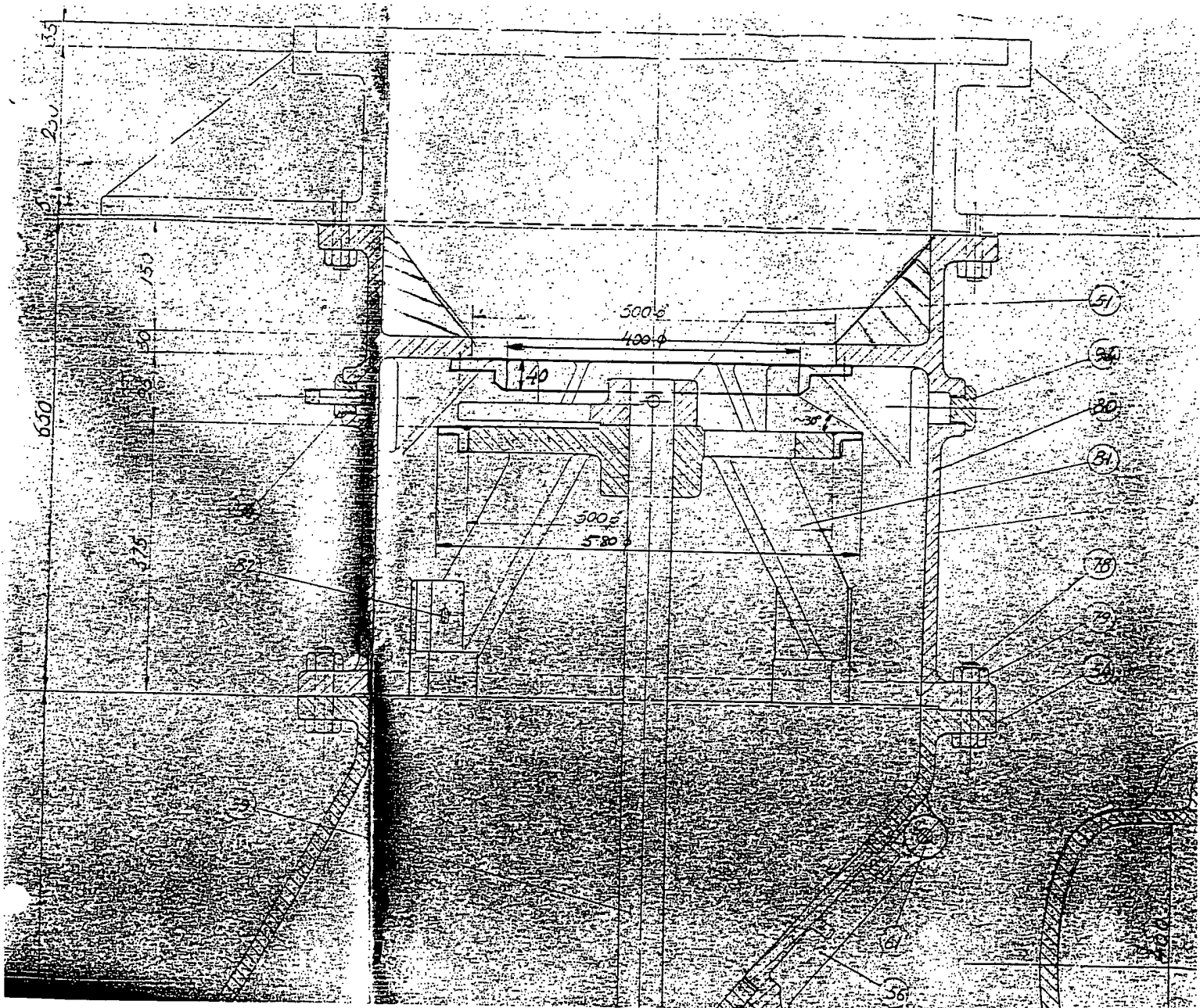
Nr	Benämning	St	Mått
39	Axel	1	1/2"
51	Minerisator	1	1/2"
52	Minerisator	1	1/2"
53	Minerisator	1	1/2"
54	Minerisator	1	1/2"
55	Minerisator	1	1/2"
56	Minerisator	1	1/2"
57	Minerisator	1	1/2"
58	Minerisator	1	1/2"
59	Minerisator	1	1/2"
60	Minerisator	1	1/2"
61	Minerisator	1	1/2"
62	Minerisator	1	1/2"
63	Minerisator	1	1/2"
64	Minerisator	1	1/2"
65	Minerisator	1	1/2"
66	Minerisator	1	1/2"
67	Minerisator	1	1/2"
68	Minerisator	1	1/2"
69	Minerisator	1	1/2"
70	Minerisator	1	1/2"

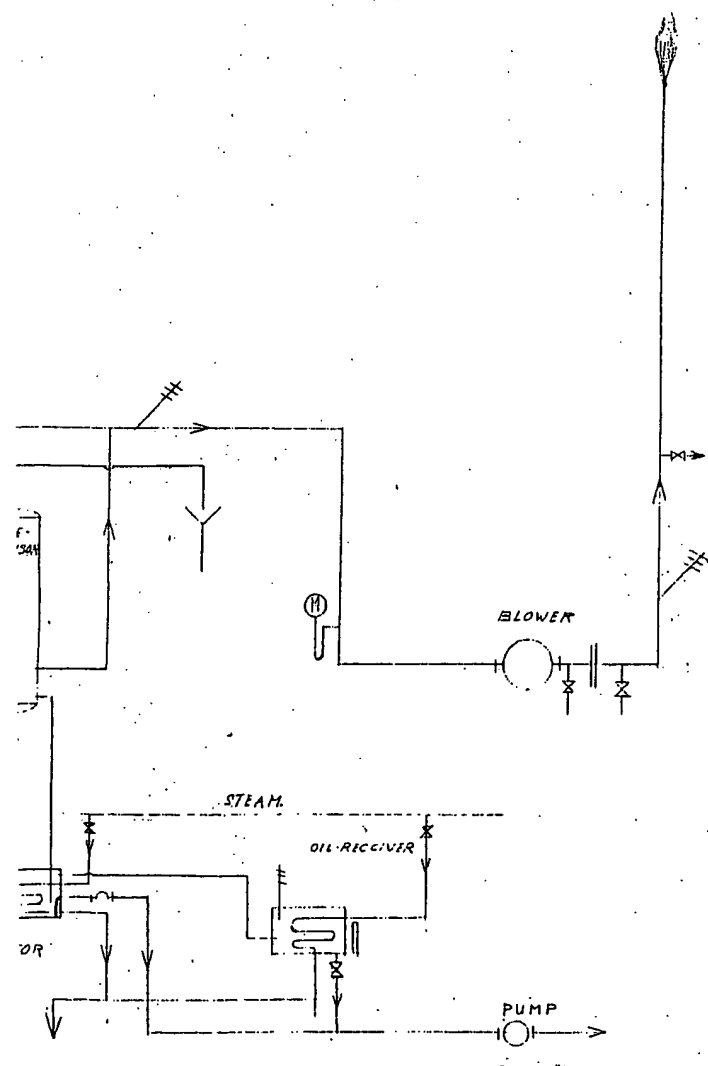
SVENSKA SKIDEROUF  
STOCKHOLM




930

13

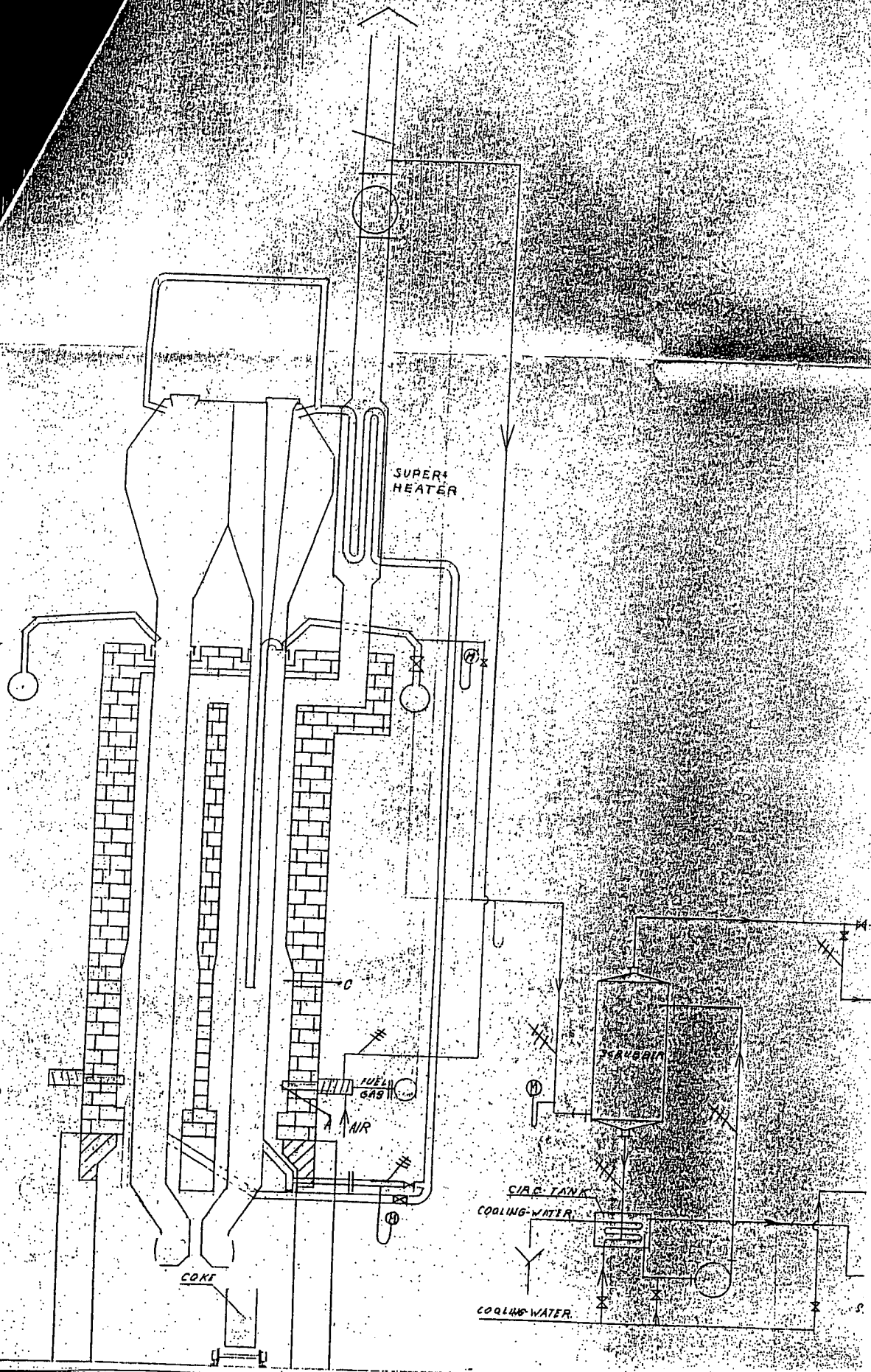
B 10





 Thermometer  
 Manometer  
 Orifice-meter

SVENSKA SKIFFEROLJ	
KYARNTORP	
FLOW SHEET FOR THE CONDE.	
COLORADO-SHALE TEST	
Datum 5.3.52	Skala
Ritad av H. G. K.	13-



UNITED STATES  
DEPARTMENT OF THE INTERIOR xxx July 4, 1953.

Bureau of Mines

Mr. Boyd Guthrie, Chief Box 792  
Oil-Shale Demonstration Branch, Colorado  
United States Department of the Interior June 8, 1953  
Bureau of Mines,  
Box 792,  
Rifle, Colorado. Airmail

U.S.A.

Mr. Hans Wibergh  
Borens Skifferolje Aktiebolaget  
Kvarntorp

Dear Mr. Guthrie:

As you already know we have continued the investigations of the Colorado shale in our Bergh-Kvarntorp furnace. We must regret that we only had 20 tons left of this shale and we have come to the conclusion that at least 50 tons still more shale would be necessary in order to fulfill the investigations in such a way that we can rely on the results. However, I herewith send you our laboratory report from the tests with the 20 tons.

If we had the possibilities to continue the test with further 50 tons we think it should be possible for us to determine at least following essential problems:

- 1) Maximum through-put of shale in our retorts.
- 2) The yield that is possible to reach when the furnace is running in the best way. The two shales are very different.
- 3) After changing the construction of the method to give additional heat to the coke burning bed and get through non-condensable gases in another way we could find out how to reproduce the advantages. It is quite really to be reached by using our Kvarntorp-system. We have very many problems to discuss and I intensively long to meet you personally in order to penetrate our experiences since we met last time at Kvarntorp. I thank you for your kind letter of June 8 with your promise to send your reports "Oil from Coal" and "Oil from Oil Shale". I am mailing you a complete set of the

Mr. Wibergh left us at the end of June this year in order to start a new company in Gothenburg, Sweden. I presume you will continue your good relations with him so I hope that the next time you visit Sweden we all can meet again and have fine days together.

With my best regards, I remain,  
a special committee studying appropriations for the Department of Interior suggested to Congress that both the Rifle oil-shale plant and the coal hydrogenation experimental station in Missouri be closed. For about a week our future was very uncertain. However, it now appears reasonably certain that we will receive our funds for at least another year, although the coal hydrogenation plant is being abandoned.

Kopia till Prof. Schjånberg,  
Dir. Hedbäck,  
Ing. Brandberg.

Copy: Mr. Carl Norgren,  
Denver.

*Rifle*  
*Per*

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
Bureau of Mines  
B x 792  
Rifle, Colorado

*Colorado*

June 8, 1953

Airmail

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggaten 3  
Örebro, Sweden

Dear Hans:

When I returned to Rifle following a three weeks' absence, I read your letter of May 12 which included a number of interesting items. The fact that you are doing further retorting experiments on our Green River shale was of particular interest to me. You mentioned that you had processed some of our shale in a recently erected pilot plant. I am wondering if this is a pilot plant designed on the Kvarntorp retorting principle and, if so, what success you have had processing our shale.

As mentioned in the report which I sent you, we feel a process designed for any particular oil shale will not be especially suited for another type of shale unless the two shales are very similar. It is rather strange yet extremely important in retort design that your shale should contain approximately half the oil and yet twice the heating value of our shale. Then, too, the available heat in your spent shale is nine times that of ours. It is quite possible, of course, that modifications of your processes may be adopted for retorting Green River shale. However, I will not go into this matter further until you have received and read the report. We will be interested to know ~~progress~~ of your progress and appreciate your viewpoint on the international shale industry.

Under separate cover I am mailing you a complete set of the 1952 Annual Report of the Secretary of the Interior consisting of the Summary, Part I - Oil from Coal, and Part II - Oil from Oil Shale. This report was released recently and contains material in which I know you will be interested.

About a month ago a special committee studying appropriations for the Department of Interior suggested to Congress that both the Rifle oil-shale plant and the coal hydrogenation experiment station in Missouri be closed. For about a week our future was very uncertain. However, it now appears reasonably certain that we will receive our funds for at least another year, although the coal hydrogenation plant is being abandoned.



May 12, 1953

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
United States Department of the Interior  
Bureau of Mines,  
Box 792,  
Rifle, Colorado.  
U.S.A.

Dear Boyd:

The answer to your letter dated April 24 has been delayed a few days due to a rather extensive traveling the last week.

We thank you for having dispatched a copy of your Report of Special Test conducted here last year. The report is not yet arrived but, when so happens, we will of course study it with care and interest.

Judging from your letter you deem our retorting processes not suitable for processing Green River shale qualities. We resp at your judgement but feel on the other hand justified to present some general viewpoints pertaining to the tests being made.

The claims earlier made here were fundamentally that the Colorado shale could well be processed in our methods. Moreover, our claims also included the position that the oil derived when distilling your shale with our methods would register a basically different quality as compared with the oil yielded at your quarters.

The first test runs verified our opinion in both instances. The shale did behave itself fairly well in the retorts and the shale crude oil derived was comparable with our oils containing 20 % and above light ends. Personally I think that this figure compares favourably with your produce. This is of course quite natural since we apply indirect heat thereby avoiding combustion of light ends in gaseous state.

On the other hand neither the thermal and general efficiency, nor the heat balances computed did display figures and values to be very proud about. Nonetheless these results cannot be evaluated independently since they did not aim to give the answer to the final suitability of our retorts. I.e. your shale was processed in one of our commercial retorts not designed and only slightly modified for the purpose of running your material. Commencing the test runs last year we actually anticipated a comparably low efficiency in the first runs and also told this to your witnesses.

However, having received a platform from which the general behavior of your shale may be spotted we have ventured into studying the problem further. The aim of approaching the problems

Dir. Redbäck.

UNITED STATES  
DEPARTMENT OF THE INTERIOR

Rifle, Colorado

April 24, 1953

AIRMAIL

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggatan 3  
Orebro, Sweden

Dear Hans:

Under separate cover I am mailing you a copy of our report on the special tests conducted about a year ago in Kvarntorp. The report, entitled "Report of Special Retorting Tests Using Colorado Oil Shale in the Swedish HG Retort", was prepared by Robert Beverly and presents similar conclusions as brought out in the report by your technicians. In general, it appears that retorting processes designed for handling your shale are not economically applicable for retorting Colorado oil shale because of the large and many differences in the two shales. However, I feel we learned a lot from the tests and have added to our knowledge of oil-shale technology as a result.

We have duplicated the report prepared by your company and distributed it to interested persons within the Bureau, along with Mr. Beverly's report. Mr. Carl Mоргren in Denver also has received a copy of our report on the tests.

Recently, I received the information from Professor Schjanberg concerning the shale reserves in Sweden and your recent production figures which I requested through you. The information is just what we wanted and I am sure it will be of use to Mr. Thorne and myself in preparing the literature on oil shale. I appreciate your efforts in this matter.

We expect to start operations on our new Gas-Combustion demonstration retorting plant in six weeks or two months. Calibration and testing of equipment has occupied a good share of our time lately. I shall keep you informed of the results of our early experiments on the unit when we have any information available.

Very truly yours,

Boyd Guthrie  
Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch

Dir. Hedback

*Col. Hedback*

UNITED STATES  
DEPARTMENT OF THE INTERIOR  
Bureau of Mines  
Box 792  
Rifle, Colorado

March 6, 1953

Air Mail

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggaten 3  
Örebro, Sweden

Dear Hans:

It was very good to hear from you again and I thoroughly enjoyed your letter of February 24. I am always encouraged in our quest for the furtherance of oil-shale technology when I read of others' keen interest such as you always show.

If you sensed a recession in the interest or development of oil shale here in the U.S., I want to inform you that we are still hard at work on many projects and have made several accomplishments over the past year. Perhaps the publicity on oil shale was not as great this year or it did not reach you.

I was interested in your remarks about oil-shale product markets in Sweden and in Europe. General demands, especially in the petroleum field, in this country are still high because of the continued defense effort, although production is beginning to catch up with the demand in many field.

To bring you up-to-date on our work at Rifle, our new demonstration-size Gas-Combustion retorting plant, which will have a throughput of 200 to 300 tons per day, is now finished. Initial operations are awaiting the completion of several major changes in our raw shale storage and distribution system which were necessitated by the new continuous retorting plant. We hope to start operations of the larger plant within about two months and no doubt we will be busy during ensuing months removing the "bugs" which always show up in a new plant and perfecting operating techniques. By the middle of the summer we should have the plant in steady operation.

Our six-ton-per-day pilot-plant retort has been in continuous operation and recently we completed an extended process variable study. A new pilot plant with a retorting capacity of about 50 tons per day also is being built which will act as a pilot for the demonstration plant, permitting mechanical changes with less expense and time and in which optimum operating conditions can be established for the larger plant.

*Colorado.*

, Sweden,

October 13, 1952.

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
United States Department of the Interior  
Bureau of Mines,  
Box 792,  
Rifle, Colorado.  
U.S.A.

Dear Boyd:

With your letter dated September 30 we received enclosed the memorandum issued by Mr. G.V. Dinnison to Mr. H.M. Thorne on July 9 this year.

In the first place accept our appreciation for your friendliness to venture into this spectrometer analysis for the purpose of permitting ourselves to compute evaluation data obtained in our laboratories. The memorandum is already submitted to our research department, the department of which is presently engaged in studying and comparing your data together with our material.

We thank you for your favourable communication as regards our report submitted you by Mr. Carl Horgren. Of course, this report could just as well have been submitted direct to you but I considered it more correct to funnel the transmission through the so called Colorado-group, which our friend Carl Horgren represents.

It should be noted that the scope of this test with Green River shale was exclusively directed for the purpose of establishing the character of Green River shale oil derived with our type of retorts. We assume this was accomplished since the crude oil received when retorting Green River shale in our retorts contained somewhat 20% light ends which compares quite favourably with the results received from crude obtained in Rifle.

On the other hand the efficiency of the retorts was comparatively low due to a series of different factors, among them improper size of shale. This efficiency factor, however, was not embedded within the test program as a paramount question. We are, of course, in the same manner as everybody else compelled to attack these problems step by step. And the retort used was one of our commercial unit deployed for the test purpose and not satisfactory for detailed control.

However, we are presently engaged in planning a new test retort based on the experiences evolved when running the Green River shale. It seems like this retort will give an answer to many problems yet unsolved and we hope to take up this matter with you within the near at f w months.

Svenska Entreprenad Akti bolaget  
Villagatan 6

STOCKHOLM

Kvarntorp

Gefret/VL

11/8 1952

Ärmed be vi få erkänna mottagandet av Edert brev av den 6 augusti 1952, och vi översända samtidigt 1 ex. av vår rapport över prov med Coloradoskiffer.

Laboratorieundersökningen, som utfördes noggrant före de praktiska proven, visar vad vi redan förut voro tåligen övertygade om, nämligen att man icke utan vidare kunde använda den ifrågavarande skiffertypen vid vår Kvarntorpsprocess. Vi voro alltså tvungna att för det praktiska provet tillämpa vår modifierade Rockesholmsmetod. Vi ha i denna retort själva ett synnerligen gott utbyte av olja per ton skiffer. Under den provperiod, som stod till förfogande för Coloradoskifferna, uppnåddes ej genomsnittligt samma goda utbyte, men under vissa provdygn kommo vi i närheten av de genomsnittsvärden, som vi erhålla för vår egen skiffer. Vi hysa inget som helst tvivel om att vi vid kontinuerlig drift skulle komma upp till utbyten på c:a 90 %. Att proven icke visa detta beror dels på den korta provningstiden, som icke medgav de justeringar, som man naturligtvis måste göra för att komma fram till optimalvärden, dels på att siktanalysen på provpartiet icke var den lämpliga för retorten ifråga. Provskiffern var nämligen nedkrossad för att passa Kvarntorpsugnen.

Provet gav emellertid besked om att den indirekta upphettningen kontra den direkta, som amerikanerna använda, ger en helt annan och förnärmigare kvalitet på oljan. Så erhöles vi sammanlagt c:a 20 - 25 % bensin, mot att amerikanerna knappast erhålla någon eller max. 1 %, och även den tyngre oljan, som vi erhöles, har säkerligen helt andra och bättre kvalitativa egenskaper än vad den direkta upphettningen ger. Dessutom får man hos oss icke obetydliga mängder icke kondenserbar gas, som håller c:a 3.000 kalorier, alltså en mycket värdefull gas, under det att de icke kondenserbara gaserna vid de amerikanska metoderna äro så gott som värdelösa.

Vi anse emellertid - och detta ha vi klargjort för våra uppdragsgivare i Colorado - att vår Rockesholmsretort icke i oförändrat skick bör komma till användning. Provdriften har emellertid givit oss anvisning på huru vi skola arbeta för att få fram en process, som ekonomiskt bör kunna hävda sig i konkurrens med de amerikanska förfarandena, varvid vi samtidigt skola se till att vi icke riskera de förnärmiga kvalitativa resultat vi erhållit. Vi ha sparat c:a 20 ton skiffer, och det är vår avsikt att i slutet av oktober eller början av november i år genomföra prov med denna kvantitet i en för ändamål tillämpad nykonstruerad ugn, som vi nu uppföra och där vi tagit vara på vunna erfarenheter i berörda avseenden. Dessa prov draga emellertid dryga kostnader, och vi skulle ansä det vara riktigt, att Coloradointressenterna på ett eller annat sätt bidra till täckandet av dessa kostnader.

August 6, 1952.

Mr. Carl A. Morgren,  
3400 South Elati St.,  
Englewood, Colorado.  
U.S.A.

Dear Carl:

In my last letter to you it was mentioned that the reports covering the Green River shale test runs were concluded and subject to various general analysis. We retained the reports here for some time in order to establish a program for our endeavours to present you a constructive proposal for the next phase of evolving the interest in U.S. for shale oil operations.

Yesterday we held a staff meeting concerning these questions and the best procedure for an intelligent development of our mutual interest. It was decided to release the reports immediately and four copies are today dispatched to you by air. Two of these copies are aimed for Boyd Guthrie and John Savage and contain each a letter from Dr. Åke Brandberg, our research specialist. In his letters to Boyd and John some details are explained regarding certain changes in the research routine.

When scrutinizing the reports you will find following:

1) The processing of the Green River shale in our retorts is carried out without difficulties, i.e. contrary to suggestions earlier displayed by several specialists interested in other schools and methods.

2) The general behavior of the shale and also the retorts during the test period harmonised fairly well with the preliminary investigations and analysis made at our research laboratories.

3) Due to the specific characteristics of the Green River shale these first test runs carried out were made in the Rockesholm unit. In our earlier correspondence with you the reasons for this routine are explained. However, by processing your shale in this retort a broad base was accomplished for the evaluation of heat balances, throughput and development possibilities.

4) The Green River shale charged in HG-retort and being crushed in Rifle maintained particle sizes definitely too small for an efficient treatment in the Rockesholm furnace. This purely physical condition of the shale produced the result of decreasing the yield and lowering the average efficiency as witnessed by John Savage and Boyd Guthrie. Moreover, the HG-retort used for the test run purp



was originally constructed for treating Swedish shales with higher calorific value and several other properties differing from American shales. In consequence, it was very difficult or almost impossible to account for all calories charged and some small mischiffs occurred during the test runs. All this, however, did not offset the general result and the definite advantages embedded in our type of retorts.

5) The crude shale oil derived displayed qualities far above the oil received from present retorts used in U.S. This, of course, is quite evident since the principle of "indirect" heating lends itself to better control and better utilization of the products evolved during the pyrolysis. When heating and combusting shale by "direct" heating the bulk of the light ends is actually destroyed. And these products may comprise perhaps the most valuable components inherited in the shale.

6) As displayed in detail in the reports the shale crude oil yielded between 16 - 24 % light products distilled below 392° F. This compares fairly with the yield of 2 - 4 % received in retorts treating the shale with "direct" heating. The general character of the crude also differs entirely from earlier experience when treating Green River shales. The permanent gases received during the pyrolysis amounted to between 108 - 163 Nm<sup>3</sup> per ton shale; these gases containing several valuable products such as absorption gasoline fractions and propane and butane hydrocarbons. The H<sub>2</sub>S concentration in the gas is low, of course due to the low sulphur content of the shale. With sizeable production units the H<sub>2</sub>S may nevertheless be utilized for the production of elemental sulphur. The oil also contains paraffin hydrocarbons pointing toward the production of paraffin waxes, a product with in fact a high market value compared to sulphur prices.

No doubt, the crude oil derived from the Green River shale when retorted in our furnaces has a much greater market value than crudes received in other retorts subject to research in U.S. Judging from the average posted price of different crudes in No 3 district the value may differ from \$ 0.75 to 1.00 per barrel.

7) On the other hand we are definitely not satisfied with the efficiency balances registered during the test runs, values of which being of decisive importance when calculating the general economics of oil shale activities. This somewhat low efficiency record is due to above mentioned conditions of the shale and the retorts as prevailed during the test run phase. Since the retorts were not calibrated for American raw material we were not able to catch all calories that should have been accounted for.

In conclusion we here all feel confident that the problem of exploiting present vast oil resources deposited in U.S. shales will eventually be stimulated by using methods yielding high quality crudes and also introducing possibilities for utilizing all components contained in the shale. And this is accomplished by our type of methods, i.e. "indirect" heating processes. This type of methods must, however, be designed and constructed for their specific purpose and the type of shale that is to be treated. The same condition exists of course when building a refinery where the units have to be designed from the viewpoint of the crude to be treated.

Already last year we reckoned that our retorts probably had to be modified for the very purpose of processing the Green River shale at a satisfactory and competitive efficiency rate. The oil derived seems sufficiently good. When negotiating the test runs last

P.M.

beträffande besök vid Bureau of Mines anläggning i Rifle,  
Colorado.

Onsdagen den 9/11 flögo vi till Rifle och mottogos där av Mr. Boyd Guthrie och Mr. Lester Schramm, som omedelbart förde oss med bil till Bureau of Mines försöksanläggning. Man fick redan vid ankomsten en imponerande bild av de skifferfyndigheter, som här förekomma och som säkerligen äro av större dimensioner än någon annan skifferförekomst i världen. Landsvägen gick utefter Coloradofloden och ca 2000 m över vägplanet såg man toppen av bergmassiven, som tämligen lodrätt stupade ned mot dalgången. Mr. Guthrie nämnde, att totala skiffermängden var upp till 800 foot och att skiffern sträckte sig över ett område om ca 650.000 acres. Oljemängden per acres, som kunde utvinna, räknas till 100.000 barrels; vilket betyder, att man här hade en potentiell tillgång av olja av ca 10 miljarder m<sup>3</sup>. Vad detta betyder, förstår man därav, att den sista uppskattningen av Amerikas kända naturliga oljetillgångar rör sig om ca 5 miljarder m<sup>3</sup>.

Skifferns oljehalt varierar naturligtvis. Den skiffer, som i dagens läge anses brytvärd, ligger relativt högt upp på slutningarna. Vi började vår genomgång med ett besök i den försöksgruva, som Bureau of Mines anlagt. Brytningen hade upplagts så, att man lämnade pelare, utgörande 25 % av den area på vilken brytningen företogs. Pelarnas mått voro 60 x 60 ft och hålrummets bredd 60 ft. Takhöjden var ca 37 ft. Brytningen skedde tidigare i tre pallar, men man hade nu övergått till tvåpallsbrytning med en pallhöjd av 37 ft. Man hade lagt ner mycket arbete på att konstruera fram effektiva borrarmaskiner. Effektiva borrhastigheten per arbetare var 200 ft/dag. Numera användes uteslutande roterande borrar (tidigare förekom i viss utsträckning stötborrar). Borrarngen skedde horisontellt med fyra borrarstänger, monterade på samma maskin. Man hade sistlidne februari haft ett allvarligt taksras och detta gjorde, att man ställde sig betänksam mot avståndet 60 ft mellan pelarna. Man räknade nog med att i framtiden få lov att minska detta avstånd. Storleken bestämdes i viss mån av att man ville ha svängrum för stora lastmaskiner, som direkt lastade skiffern i truckar. Brytningskostnaderna uppgavs till 30 cents/ton, vilken siffra dock vid senare konferenser korrigerades till 38 cents/ton skiffer, lastad i truck vid gruvans mynning. Allt brutet gods inräknades då såsom fyndigt berg.

Därefter besöktes retortanläggningen. Skiffern krossades i tur och ordning i en vanlig Blakes tuggare, en hammarkross och i en konkross. Allt gods finare än 1/4" avsållades. Den ugnstyp, som konstruerats av Bureau of Mines, den B.K. Gas Combustion Retort, finns beskriven i litt. Det bör observeras, att man vid

konstruktionen gått ut ifrån att så små kvantiteter vatten som möjligt skulle få komma till användning, då man icke har någon möjlighet att skaffa vatten på annat sätt än genom att pumpa upp detsamma från Coloradofloden. För kondenseringen kunde vatten icke komma ifråga. Metoden bygger på att de icke kondenserbara gaserna återföras och förbrännas i retorten tillsammans med skiffern. Pyrolysen sker i en zon ovanför förbränningen och pyrolysisprodukterna avsugas upptill. Under passagen genom den kalla skiffern kondenserar oljan. Det är därvid av väsentlig betydelse att de fina dropparna inte flyta samman på skifferbitarnas yta. I stället erhålles hela oljekvantiteten i form av en fin dimma. Dimman slås ned i en rotoklon, varjämte man har en restavskiljning i elektrofilter. Oljeutbytet uppgavs till 95 - 98 % i den lilla försöksanläggningen, som tidigare körts. I den nuvarande anläggningen, som hade en genomsättning av 160 ton/dag, hade man ännu icke uppnått så goda resultat (förmodligen ej mer än 90 %). Kolet i den bildade koksen förbrändes icke, då den utvinnbara kalorimängden är så liten, att man icke vill komplicera processen genom att använda denna del av skifferns värmeinnehåll. Utgående koksens temperatur är under 200°F.

För provraffinering av den producerade skifferoljan hade man ett litet raffinaderi med en Dubbs krackningsanläggning. Oljan, som erhålles ur retorten, är nämligen en mycket tung olja med en besninhalt av endast några få %. Den krackade oljan raffinerades med koncentrerad svavelsyra under mycket stora volymsförluster. Det ansågs, att helt andra raffineringsmetoder måste komma till användning om en produktion kommer till stånd.

Hittills har amerikanska staten genom Bureau of Mines lagt ned 14 milj. dollar vid Rifle och därtill 6 milj. dollar vid Laramie, där det mer vetenskapligt lagda studiet av skifferprodukterna ägde rum. För dagen är situationen den, att man i Kongressen överväger huruvida arbetet vid Rifle och Laramie skall fortsätta att hållas i drift eller ej. Man anser, att amerikanska regeringen utfört tillräckligt grundläggande arbete och att det nu ankommer på den privata industrin att ta vid. Man är i USA bestämd motståndare till att staten som sådan skall driva kommersiella anläggningar.

Mr. Guthrie nämnde att, såvitt man kände till, endast Union Oil för närvarande höllo på med skifferforskning. Tidigare hade Standard Oil of New Jersey byggt en försöksanläggning enligt fluid-bed-principen. Man hade emellertid avbrutit försöken då man icke kunde komma till rätta med den höga halten skifferdamm i oljan.

Mr. Guthrie omtalade också, att man från utlandet visat intresse för Bureau of Mines skifferförsök. Mr. José Schor från Brasilien (som även besökt Kvarntorp) har studerat Rifle-anläggningen. Det synes som om man nu äntligen övergivit tanken på bearbetning av den våta Paraíba-skiffern i Brasilien och börjat studera en annan skifferförekomst (Irak ?). Även från Jugoslavien hade en tekniker besökt Rifle. Mr. Guthrie trodde, att man i Jugoslavien på egen hand börjat bygga en gas combustion retort. Vissa ritningar o.d. hade Bureau of Mines ställt till förfogande.

Santa Cruz den 13 november 1955.

Claes Gejrot

## 02011074

The first of these is the fact that the
 majority of the population of the
 United States is now living in
 urban areas. This is a result of
 the process of urbanization, which
 has been going on since the
 beginning of the 20th century.
 The second is the fact that the
 majority of the population of the
 United States is now living in
 the South and West. This is a
 result of the process of
 migration, which has been going
 on since the beginning of the
 20th century. The third is the
 fact that the majority of the
 population of the United States
 is now living in the
 industrial belt. This is a result
 of the process of industrialization,
 which has been going on since
 the beginning of the 19th century.
 The fourth is the fact that the
 majority of the population of the
 United States is now living in
 the agricultural belt. This is a
 result of the process of
 agriculturalization, which has
 been going on since the
 beginning of the 19th century.
 The fifth is the fact that the
 majority of the population of the
 United States is now living in
 the service belt. This is a result
 of the process of
 serviceization, which has been
 going on since the beginning of
 the 20th century.

74-10000, 10001, 10002, 10003, 10004, 10005, 10006, 10007, 10008, 10009, 10010, 10011, 10012, 10013, 10014, 10015, 10016, 10017, 10018, 10019, 10020, 10021, 10022, 10023, 10024, 10025, 10026, 10027, 10028, 10029, 10030, 10031, 10032, 10033, 10034, 10035, 10036, 10037, 10038, 10039, 10040, 10041, 10042, 10043, 10044, 10045, 10046, 10047, 10048, 10049, 10050, 10051, 10052, 10053, 10054, 10055, 10056, 10057, 10058, 10059, 10060, 10061, 10062, 10063, 10064, 10065, 10066, 10067, 10068, 10069, 10070, 10071, 10072, 10073, 10074, 10075, 10076, 10077, 10078, 10079, 10080, 10081, 10082, 10083, 10084, 10085, 10086, 10087, 10088, 10089, 10090, 10091, 10092, 10093, 10094, 10095, 10096, 10097, 10098, 10099, 10100, 10101, 10102, 10103, 10104, 10105, 10106, 10107, 10108, 10109, 10110, 10111, 10112, 10113, 10114, 10115, 10116, 10117, 10118, 10119, 10120, 10121, 10122, 10123, 10124, 10125, 10126, 10127, 10128, 10129, 10130, 10131, 10132, 10133, 10134, 10135, 10136, 10137, 10138, 10139, 10140, 10141, 10142, 10143, 10144, 10145, 10146, 10147, 10148, 10149, 10150, 10151, 10152, 10153, 10154, 10155, 10156, 10157, 10158, 10159, 10160, 10161, 10162, 10163, 10164, 10165, 10166, 10167, 10168, 10169, 10170, 10171, 10172, 10173, 10174, 10175, 10176, 10177, 10178, 10179, 10180, 10181, 10182, 10183, 10184, 10185, 10186, 10187, 10188, 10189, 10190, 10191, 10192, 10193, 10194, 10195, 10196, 10197, 10198, 10199, 10200, 10201, 10202, 10203, 10204, 10205, 10206, 10207, 10208, 10209, 10210, 10211, 10212, 10213, 10214, 10215, 10216, 10217, 10218, 10219, 10220, 10221, 10222, 10223, 10224, 10225, 10226, 10227, 10228, 10229, 10230, 10231, 10232, 10233, 10234, 10235, 10236, 10237, 10238, 10239, 10240, 10241, 10242, 10243, 10244, 10245, 10246, 10247, 10248, 10249, 10250, 10251, 10252, 10253, 10254, 10255, 10256, 10257, 10258, 10259, 10260, 10261, 10262, 10263, 10264, 10265, 10266, 10267, 10268, 10269, 10270, 10271, 10272, 10273, 10274, 10275, 10276, 10277, 10278, 10279, 10280, 10281, 10282, 10283, 10284, 10285, 10286, 10287, 10288, 10289, 10290, 10291, 10292, 10293, 10294, 10295, 10296, 10297, 10298, 10299, 10300, 10301, 10302, 10303, 10304, 10305, 10306, 10307, 10308, 10309, 10310, 10311, 10312, 10313, 10314, 10315, 10316, 10317, 10318, 10319, 10320, 10321, 10322, 10323, 10324, 10325, 10326, 10327, 10328, 10329, 10330, 10331, 10332, 10333, 10334, 10335, 10336, 10337, 10338, 10339, 10340, 10341, 10342, 10343, 10344, 10345, 10346, 10347, 10348, 10349, 10350, 10351, 10352, 10353, 10354, 10355, 10356, 10357, 10358, 10359, 10360, 10361, 10362, 10363, 10364, 10365, 10366, 10367, 10368, 10369, 10370, 10371, 10372, 10373, 10374, 10375, 10376, 10377, 10378, 10379, 10380, 10381, 10382, 10383, 10384, 10385, 10386, 10387, 10388, 10389, 10390, 10391, 10392, 10393, 10394, 10395, 10396, 10397, 10398, 10399, 10400, 10401, 10402, 10403, 10404, 10405, 10406, 10407, 10408, 10409, 10410, 10411, 10412, 10413, 10414, 10415, 10416, 10417, 10418, 10419, 10420, 10421, 10422, 10423, 10424, 10425, 10426, 10427, 10428, 10429, 10430, 10431, 10432, 10433, 10434, 10435, 10436, 10437, 10438, 10439, 10440, 10441, 10442, 10443, 10444, 10445, 10446, 10447, 10448, 10449, 10450, 10451, 10452, 10453, 10454, 10455, 10456, 10457, 10458, 10459, 10460, 10461, 10462, 10463, 10464, 10465, 10466, 10467, 10468, 10469, 10470, 10471, 10472, 10473, 10474, 10475, 10476, 10477, 10478, 10479, 10480, 10481, 10482, 10483, 10484, 10485, 10486, 10487, 10488, 10489, 10490, 10491, 10492, 10493, 10494, 10495, 10496, 10497, 10498, 10499, 10500, 10501, 10502, 10503, 10504, 10505, 10506, 10507, 10508, 10509, 10510, 10511, 10512, 10513, 10514, 10515, 10516, 10517, 10518, 10519, 10520, 10521, 10522, 10523, 10524, 10525, 10526, 10527, 10528, 10529, 10530, 10531, 10532, 10533, 10534, 10535, 10536, 10537, 10538, 10539, 10540, 10541, 10542, 10543, 10544, 10545, 10546, 10547, 10548, 10549, 10550, 10551, 10552, 10553, 10554, 10555, 10556, 10557, 10558, 10559, 10560, 10561, 10562, 10563, 10564, 10565, 10566, 10567, 10568, 10569, 10570, 10571, 10572, 10573, 10574, 10575, 10576, 10577, 10578, 10579, 10580, 10581, 10582, 10583, 105

— 17. 8. Answered at 5 1/2.

**CAL HEAT GENERATION PLANT** set up by the Bureau of Mines near Butte, Cal., includes crushers and P.F.O. tanks, at the top of the processing area. To the right is the refinery and to the left are the plant service buildings. To the left of the P.F.O. tanks is the mill track, the mill plant and laboratory buildings. Tests have been running at this pilot plant for six months and the plant is being considered for full-scale work.

## PRODUCTION

### Gas Combustion Process Undergoes Tests; Result in Cheap Oil from Oil Shale

With preliminary engineering and design work already under way, a new plant will be in operation next year at Rifle, Col., employing a new and very promising process for the continuous extraction of oil from oil shale.

Under the supervision of the U. S. Bureau of Mines, construction has been awarded to Blaw-Knox Construction Co. Major objectives of the new retorting plant are:

- ▶ To determine cost and yield data that will permit an accurate evaluation of the "gas-combustion" process;
- ▶ To provide the technical information that industry needs to design commercial plants;
- ▶ To supply crude shale oil in the quantities required for the Bureau's refining studies.

The new demonstration retort will be patterned after 6-ton-a-day pilot plant which has proved the new "gas-combustion" process both the most efficient and the most economical ever tested at Rifle. Capacity will range from 150 to 400 tons of oil shale daily. Plant design will permit a wide range of experimental operating conditions, and will include all necessary instrumentation for accurate process control and exact measurement of results.

The gas-combustion process was developed by the Bureau's staff at Rifle during intensive studies made to determine a simple yet efficient and low-cost continuous method for extracting oil from the immense reserves of oil shale in northwestern Colorado.

For about six months, now, tests run in the Bureau's all pilot plant have revealed good oil recoveries at high throughput rates. However, only the new demonstration unit can confirm development research and apply it on a scale that will translate theoretical results to concrete facts essential to private industry concerning commercial production.

There are two important features connected with the new process:

It produces and uses as a source of heat for retorting a low B. t. u. gas obtained from the shale and burned in the presence of air.

Unlike most other retorting processes, it requires neither water nor an elaborate system for condensing liquid products that come from the retort in the form of mist. (Water, in this semi-desert area, is a scarce and valuable commodity.)

Even more important, investment and operating costs for the new process will be substantially lower than for other processes tested by the Bureau, thus insuring a lowering of product costs. Although the grade of oil obtained by means of the new process will be somewhat inferior to average petroleum, finished products of good quality can and will be refined from it.

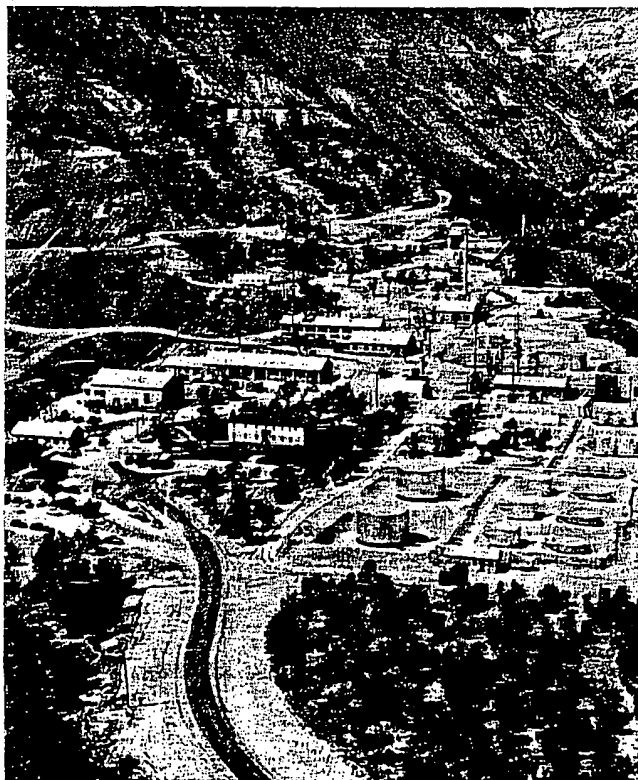
The system works something like this. Crushed oil shale is fed into the top of the vertical retort and moves

downward by gravity against a rising stream of gas. Air is injected near the center of the vessel and the gas burned to provide heat for retorting. As the rising gas from the combustion zone and the downward moving shale pass each other, the shale is heated and the gas is cooled. Upon leaving the retort, the oil-mist-laden gases pass through an oil-collecting system. Part of it is returned to the bottom of the retort where it is pre-heated by spent shale before entering the combustion zone. The large volume of excess gas remaining could be burned to generate heat or power.

There are several further advantages in favor of the gas-combustion retort:

- ▶ The design is extremely simple, with a minimum of moving parts;
- ▶ Construction and operating costs are low;
- ▶ The retort can be easily enlarged for mass-production operations;
- ▶ It has a higher retorting rate or greater output per unit of area than most other retorts.

During a recent 10-day test run at Rifle, a pilot plant retort using this process achieved a high recovery of liquid oil and demonstrated high capacity. The oil yield averaged 96 percent of the Fisher assay value of the shale treated, and the retort handled 230 pounds



—U. S. Bureau of Mines

OIL-SHALE DEMONSTRATION PLANT set up by the Bureau of Mines near Rifle, Col., includes crushers and B.T.U. retorts, at the far end of the processing area. To the right is the refinery and to the left, office and plant service buildings. To the left of the boiler-house's tall smoke stack are pilot plant and laboratory buildings. Tests have been running at this pilot plant for six months and, the process has demonstrated a good oil recovery rate.

ve  
now  
see  
med  
field  
analysis  
at  
anges

## BULLETIN BOARD . . .

**Solder**—A brochure on the nature, properties and uses of solder has been published by Federated Metals Division, American Smelting and Refining Co., New York, N. Y. Profusely illustrated, the 36-page book has been designed primarily as a reference work for both the layman and the technician.

**Machine Tools**—A new up-to-date edition of The Cincinnati Milling Machine Co.'s general catalog (No. M-1712) has been released, with new colors and introductory treatment. Cincinnati offers also a completely new, illustrated booklet on its 8-by-18-inch tool and die miller.

**Diesels**—Several diesel models produced by International Harvester Co. are described in new bulletins just issued by the company: Catalog No. E-51-A covers all six four-cycle power units, ranging from 45 to 180 hp. and capable of powering saw mills, rock crushing plants, hoists, shovels, pumping installations and portable crushing plants; the largest diesel crawler tractor—TD-24—suitable for snaking out heavy logs, laying the largest pipe, coal stripping, highway filling, is covered in Folder E-27-A; Folder E-29-A covers model TD-6, which compacts and loads fill, lays telephone cable, clears and grades building sites.

**Motors**—The totally-enclosed, fan-cooled motors produced by Allis-Chalmers are described in a new bulletin (05B7150A), available from the company's Milwaukee, Wis. office. Bulletin covers squirrel-cage, wound-rotor and synchronous types for both horizontal and vertical installation.

of shale an hour for each square foot of bed area. Quality of the oil was comparable in every respect with that from other retorts in which secondary cracking is kept at a minimum.

**Highlight:** On the basis of the test-run results, a detailed engineering and economic evaluation of the process is now being made. If this evaluation and further tests confirm its indicated merit, the Bureau of Mines will consider building a 300-ton-per-day pilot plant to demonstrate the engineering and economic feasibility of the gas-combustion process for commercial scale operations.

If the considerable investment and product cost reduction indicated by preliminary analysis is combined with other improvements in technique, over-all capital investment for commercial-scale operation of the new process is expected to be at least 25 percent under previous Bureau estimates. Guess is that the new "gas combustion" process may be the answer to the shale oil problem.

## RESEARCH

### Socony-Vacuum Awards Physics Fellowship

A total of \$2,000 was awarded to Brown Univ. (Providence, R. I.) by The Socony-Vacuum Oil Inc., for the continuation of a fellowship in physics the coming year.

During the 1951-1952 academic year, Socony-Vacuum will support a total of 20 fellowships at college universities throughout the country, at a total cost of \$40,000.

Continuing the program instituted several years ago by the company, recipients of the fellowship are selected by the universities and colleges from students who have completed at least one year of graduate work. No restrictions are placed on the recipients by the company regarding future employment and publication of the results of their investigations. The student is free to study subjects other than those connected with the petroleum industry. A major portion of the fellowship stipends are paid from Socony-Vacuum to the students, to help defray living costs.

### Bureau of Mines Studies Beryl Recovery

Beryl, a mineral vital to industrial production, is the object of a research program now being undertaken by the Bureau of Mines. At the present time, no practical commercial method exists for recovering minute quantities of beryl crystals.

Mining engineers are now opening up a pegmatite deposit in the Black Hills of South Dakota for research purposes (beryl occurs in pegmatite deposits, along with other unusual mineral formations), in an attempt to discover some practical way to mine and recover beryl and the other minerals found in pegmatite deposits.

**Highlight:** Beryllium, the metal, is used in the manufacture of x-ray tube windows and as an alloying agent with copper. Success in this recovery program would mean more plentiful and cheaper supplies of this material for many different phases of industry.

### Helium's New Bottle Keeps Cold 100 Days

Only just out of the laboratory, a new vacuum bottle is helping scientists and researchers study the behavior of matter at super-cold temperatures.

By the use of this bottle, developed at the Westinghouse Research Laboratories, it is now possible to store liquid helium, the coldest liquid known to man, in liquid form over long distances. The new bottle keeps helium at a temperature 8 degrees above absolute zero for longer than 100 days—a vast improvement over the performance of containers now used.

The new bottle is made of copper in the form of a sphere and immersed in liquid nitrogen at 300 degrees below zero. To counteract the tremendous pressure which liquid helium builds up when it evaporates, a tiny opening has been made at the top of the container. Helium is in wide demand by natural scientists everywhere, and the fact that it can now be shipped so easily



Mr. John W. Savage  
Savage Oil Shale Development Company  
P.O. Box 112  
De Beque, Colorado

(Gösta Salomonsson)

一、在政治上，要坚决拥护党的领导，拥护社会主义制度，拥护党的路线、方针、政策，在思想上、政治上、行动上同党中央保持高度一致。

二、在组织上，要自觉遵守党的纪律，服从组织分配，积极参加党的各项活动，按时缴纳党费。

三、在工作、学习和生活中，要严格要求自己，刻苦钻研业务，不断提高业务水平，为党的事业贡献自己的力量。

四、在作风上，要密切联系群众，全心全意为人民服务，保持艰苦奋斗、勤俭节约的优良传统。

五、在道德上，要遵守社会公德、职业道德、家庭美德，做到诚实守信、尊老爱幼、邻里和睦。

六、在纪律上，要自觉遵守国家的法律法规，遵守社会公共秩序，不得有违法乱纪行为。

七、在个人生活方面，要树立正确的世界观、人生观、价值观，保持健康的生活情趣，自觉抵制不良风气的侵蚀。

八、在家庭方面，要孝敬父母，关心子女，维护家庭和谐，做合格的家庭成员。

九、在社会交往方面，要诚实守信，乐于助人，积极参与社会公益活动，为社会和谐稳定做出积极贡献。

十、在自我修养方面，要不断加强学习，提高自身素质，做到知行合一，在实践中不断成长。

, Sweden,  
August 6, 1952.

Mr. Carl A. Mоргren,  
3400 South Elati St.,  
Englewood, Colorado.  
U.S.A.

Dear Carl:

In my last letter to you it was mentioned that the reports covering the Green River shale test runs were concluded and subject to various general analysis. We retained the reports here for some time in order to establish a program for our endeavours to present you a constructive proposal for the next phase of evolving the interest in U.S. for shale oil operations.

Yesterday we held a staff meeting concerning these questions and the best procedure for an intelligent development of our mutual interest. It was decided to release the reports immediately and four copies are today dispatched to you by air. Two of these copies are aimed for Boyd Guthrie and John Savage and contain each a letter from Dr. Åke Brandberg, our research specialist. In his letters to Boyd and John some details are explained regarding certain changes in the research routine.

When scrutinizing the reports you will find following:

1) The processing of the Green River shale in our retorts is carried out without difficulties, i.e. contrary to suggestions earlier displayed by several specialists interested in other schools and methods.

2) The general behavior of the shale and also the retorts during the test period harmonized fairly well with the preliminary investigations and analysis made at our research laboratories.

3) Due to the specific characteristics of the Green River shale these first test runs carried out were made in the Rockeshelm unit. In our earlier correspondence with you the reasons for this routine are explained. However, by processing your shale in this retort a broad base was accomplished for the evaluation of heat balances, throughput and development possibilities.

4) The Green River shale charged in HG-retort and being crushed in Rifle maintained particle sizes definitely too small for an efficient treatment in the Rockeshelm furnace. This purely physical condition of the shale produced the result of decreasing the yield and lowering the average efficiency as witnessed by John Savage and Boyd Guthrie. Moreover, the HG-retort used for the test run purposes

was originally constructed for treating Swedish shales with higher calorific value and several other properties differing from American shales. In consequence, it was very difficult or almost impossible to account for all calories charged and some small mischiefs occurred during the test runs. All this, however, did not affect the general result and the definite advantages embodied in our type of retorts.

5) The crude shale oil derived displayed qualities far above the oil received from present retorts used in U.S. This, of course, is quite evident since the principle of "indirect" heating lends itself to better control and better utilization of the products evolved during the pyrolysis. When heating and combusting shale by "direct" heating the bulk of the light ends is actually destroyed. And these products may comprise perhaps the most valuable components inherited in the shale.

6) As displayed in detail in the reports the shale crude oil yielded between 16 - 24 % light products distilled below 392° F. This compares fairly with the yield of 2 - 4 % received in retorts treating the shale with "direct" heating. The general character of the crude also differs entirely from earlier experience when treating Green River shales. The permanent gases received during the pyrolysis amounted to between 100 - 160 Nm<sup>3</sup> per ton shale; these gases containing several valuable products such as absorption gasoline fractions and propane and butane hydrocarbons. The H<sub>2</sub>S concentration in the gas is low, of course due to the low sulphur content of the shale. With sizeable production units the H<sub>2</sub>S may nevertheless be utilized for the production of elemental sulphur. The oil also contains paraffin hydrocarbons pointing toward the production of paraffin waxes, a product with in fact a high market value compared to sulphur prices.

No doubt, the crude oil derived from the Green River shale when retorted in our furnaces has a much greater market value than crudes received in other retorts subject to research in U.S. Judging from the average posted price of different crudes in No 3 district the value may differ from \$ 0.75 to 1.00 per barrel.

7) On the other hand we are definitely not satisfied with the efficiency balances registered during the test runs, values of which being of decisive importance when calculating the general economics of oil shale activities. This somewhat low efficiency record is due to above mentioned conditions of the shale and the retorts as prevailed during the test run phase. Since the retorts were not calibrated for American raw material we were not able to catch all calories that should have been accounted for.

In conclusion we here all feel confident that the problem of exploiting present vast oil resources deposited in U.S. shales will eventually be stimulated by using methods yielding high quality crudes and also introducing possibilities for utilizing all components contained in the shale. And this is accomplished by our type of methods, i.e. "indirect" heating processes. This type of methods must, however, be designed and constructed for their specific purpose and the type of shale that is to be treated. The same condition exists of course when building a refinery where the units have to be designed from the viewpoint of the crude to be treated.

Already last year we reckoned that our retorts probably had to be modified for the very purpose of processing the Green River shale at a satisfactory and competitive efficiency rate. The oil derived seems sufficiently good. When negotiating the test runs last

year we suggested to treat the Green River shale in a Kvarntorp unit and actually commenced erecting a pilot plant. Without knowing the behavior of your shale the proper design of this pilot plant was not exactly established. Based on present experience and values received from the test runs last spring we will proceed immediately with the final erection of mentioned pilot plant, the design being modified by the knowledge now received. This plant will be ready for operation in October this year.

With this modified Kvarntorp pilot plant we will process the remaining quantity of the Green River shale still in our possession, some 20 tons. Based on this we will submit you a proposal for the development of an attractive retort especially designed for treating Colorado shale. It may occur that these development costs might be a little high for pure speculative purposes. Therefore, we might both consider whether some cooperative agreement could be drawn where some contribution from your party of interest could be negotiated. Permit me to return to all this in a couple of months when we can judge the results from mentioned test in October.

With the very best regards to you.

Sincerely yours,

SVENSKA SKIFFEROLJE AKTIEBOLAGET

H.C. Fjörberg  
Vice President in Charge of Sales

Kopia till Dir. Gajrot,  
Prof. Schjånberg,  
Dir. Hedbäck,  
Övering. Salomonsson,  
Ing. Brandberg.

SAVAGE OIL SHALE DEVELOPMENT COMPANY

P. O. BOX 112  
DE BEQUE, COLORADO

TELEPHONE 6-J

JOHN W. SAVAGE

April 10, 1952

Dr. Gesta Salomonsson  
Svenska Skifferolje Aktiebolaget  
Drottninggatan 3, Orebro  
Sweden

Dear Dr. Salomonsson:

I want to thank you for the very great consideration you gave me during the tests at Kvarntorp. It was a great pleasure to work with you and it was also extremely informative.

Did you have a pleasant trip? I hope it was and also that it was profitable. I judge by the news reports that it was successful.

I have had the flu since I returned, but all is well now that spring is here.

Enclosed is a copy of a paper by Jean Barlet. I know of no confirmation of his work and there is considerable doubt that it has any validity in respect to Colorado shale. What do you think? However, if it is true concerning some pyrolysis reactions isn't it logical to presume that a hydrogen atmosphere has some effect in the pyrolysis of kerogen.

Please give my best wishes to Prof. Schanberg. I hope he has fully recovered. We were pleased to get copies of his "Fuel" paper and also his paper on "Some Research Problems which have been Studied in Kvarntorp".

I'm sorry you didn't get to Colorado this visit, but I surely hope to see you here in the not to distant future.

My very warmest regards to you and your staff and thank you again.

Sincerely yours,

*John W. Savage*

2 Encl.

## HIDROGENATION OF BITUMINOUS SHALES UNDER ORDINARY PRESSURE

In a natural atmosphere, it is Jean-Baptiste (1) who observed the rapid conversion of the gas and liquid forms. Presented by Mrs. Delapina, in a reducing atmosphere, the observation of these conditions has much less importance.

Compt rend 201, 1197-8 (1935)

(Translated by S. S. Fihen, Bureau of Mines, Laramie, Wyoming, September 29, 1947).

Abstract

The pyrogeneration of bituminous shales in an atmosphere of nitrogen, of carbon dioxide or of water vapor transforms a variable quantity of the total organic matter into oil and gas.

Fields of Crude Oil, Percent 25 15 5.5 5  
This crude oil is a complex mixture in unstable equilibrium and in which condensation and polymerization reactions are produced spontaneously. By fractional distillation one may separate a series of more or less volatile hydrocarbons, and there remains a fixed residue, asphalt, in the proportion of about 25 to 35 per cent of the total quantity of the oil. The liquid part contains on the average about 40 to 60 per cent of unsaturated hydrocarbons; on the other hand, the gas evolved in the course of the pyrogeneration contains a notable quantity of free hydrogen, perhaps as much as 40 per cent by weight.

These factors allow one to believe that pyrogeneration in the presence of an excess of hydrogen should change considerably the nature of the products obtained. In fact, recent work has established that hydrogenation of certain shales under elevated pressure greatly augments the yield and improves the quality of the products formed (2). (3) (4) (5). (6) Series, No. 1, 1934, p. 1911.

We have had such results, without the addition of a catalyst, and under a pressure essentially equal to atmospheric, when distilling shales of various origins, in pure hydrogen or industrial hydrogen, or in mixtures of carbon dioxide and hydrogen containing at least 60 per cent of the latter. Under these conditions the yield of crude oil is slightly increased (5 to 10 per cent); the condensed products still contain a large proportion of unsaturated hydrocarbons (about 25 to 30 per cent), but upon fractionation they distilled entirely below 360° C. and gave only a small quantity of asphalt (0.5 to 1.5 per cent). The asphalt is a product of inferior value; its nearly total suppression gives a considerable increase in the percentage of the light oils, and thus one may visualize the exploitation of deposits which are at present considered too poor.

The apparatus employed is of the same type as that previously described for making analyses and studies of yields (3). It is composed essentially of one or more steel tubes of 4 cm. diameter and 40 cm. length, heated electrically, or with burners to 500° to 600° C. for two-thirds of their surface. The hydrogen or a mixture of gases rich in hydrogen enters at one end. Condensation is in a flask surrounded with water followed by a Schaelet tube cooled to minus 70° C., or by a gas-oil wash.

It is not necessary to dry the hydrogen nor to purify it before use; also, it is useless to inject super-heated steam, and also the shale may be distributed in the tubes without special precautions.



In a neutral atmosphere, it is necessary to assure the rapid evacuation of the gas and liquids formed to avoid secondary reactions; in a reducing atmosphere, the observation of these conditions has much less importance.

Here are several characteristics of oils obtained from several samples of shales:

	Estonian Kukersite	Autun Shale	Creveney Shale	Chili Shale
Yields of Crude Oil, Percent	23	13	6.5	5
Distilled Between	45°-360°C.	42°-350°C.	40°-330°C.	42°-345°C.
Asphalt Content, Percent	1.5	1.1	0.8	1
Total Sulfur, Percent	0.34	0.18	1.45	0.40
Heating Value (calories)	10,485	10,805	10,665	10,780

The greatest portion of the sulfur is eliminated in the course of pyrogenation as hydrogen sulfide without its producing any appreciable attack on the steel tubes.

- (1). Meeting of 18th, November 1934.
- (2). V. P. Tsuibasov and V. P. Efremov. Fatty Materials, Petroleum and Its Derivatives, No. 323, March 15, 1935, p. 10,443.
- (3). J. Barlot. (Bull. soc. chim. de France), 5th series, No. 1, 1934, p. 1014.

Summary.

Senaste på försöksdrift grundade kostnadsuppskattning för skifferbrytning - krossning och -transport (nov. 1950) visar följande:

Direct supervision	0.0113 \$/ton
Drilling	0.306
Blasting	0.648
Loading	0.209
Transportation	0.527
Scaling	0.07
Electrical distribution	0.212
Miscellaneous	0.252

∴ Total Direct costs 0.2368

Total costs 0.4263 \$/ton (interest on capital excluded)

Capital investment 247.40 \$/hr/day

Depreciation rate per year 11.6 %

Labor percentage of total direct costs 39.7 %

Total daily tonnage 19,200

Labor: Tons per 8-hour man-shift (underground) 165.5

Tons per ——— (Total payroll) 99.5

Total number of employees 277

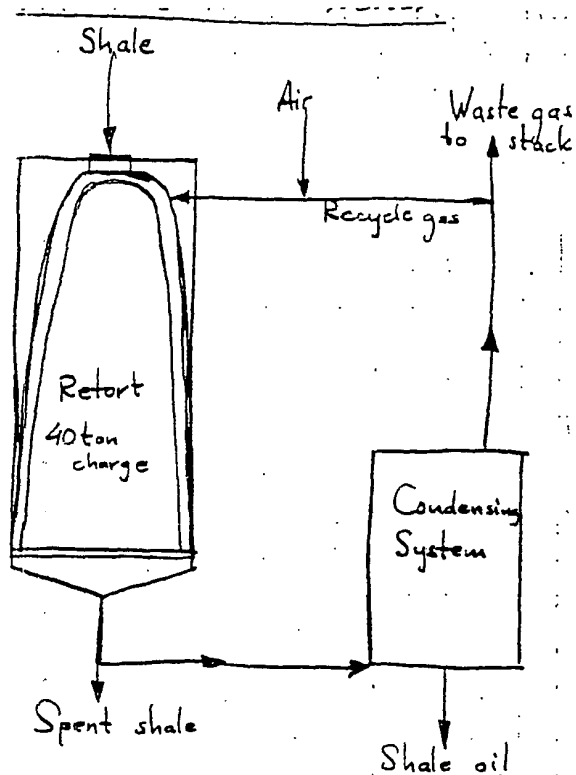
Power: kW-hrs/ton 3.12

Tons broken per pound of explosive 3.1

Tons broken per foot of drill hole 2.8

Gallons of fuel per ton 0.060

Gallons of water per ton 2.7

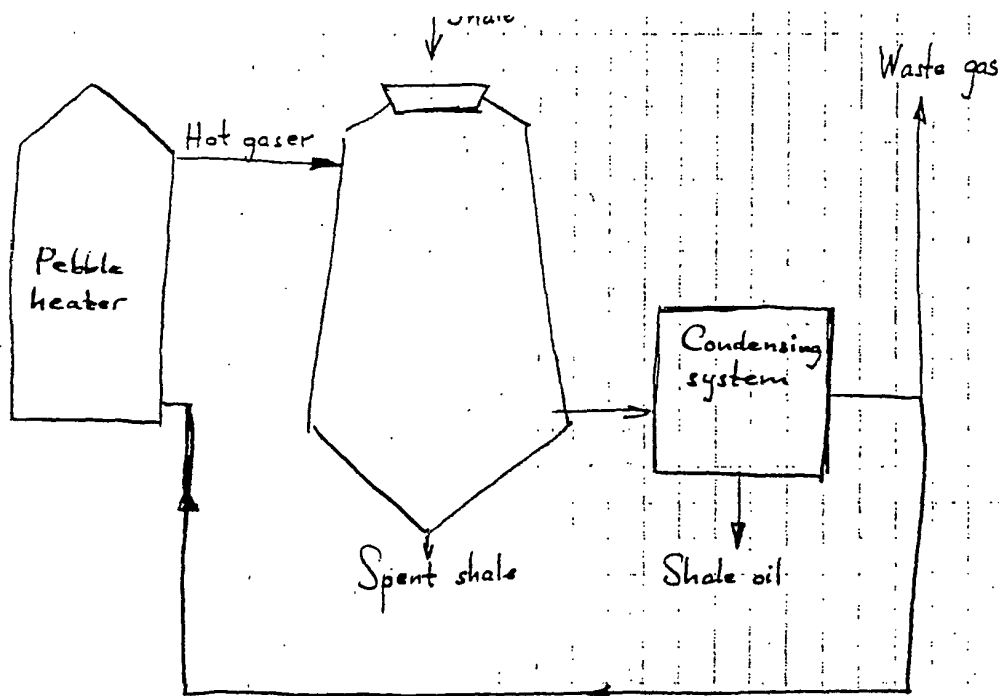


Den fööklerserie ändrade luft-  
hastigheten från 150 s.c.f.m.  
till 850 s.c.f.m. Ojensbylat  
gick då från 80 till 67% av Fi.

En typisk ojeanalyse:

Gravity: 22.8 API = 0.917

För en stor-skala-anläggning  
kan man kalkylerat en färd-



Princip: En del av den skondenserbare gasen värms i en pebble heater och recirkuleras in i reaktor. God värmeöverföring och  $\approx$  ca. 100% utbyte, av Fischer. Högre utbyten, än mindre konststolek.

Reaktorn köldes också med överhettad vattenånga i st. f. recycle gas, vilket resulterade i något högre gasutbyte och högre halt av  $H_2S$  och  $CO$  i gasen.

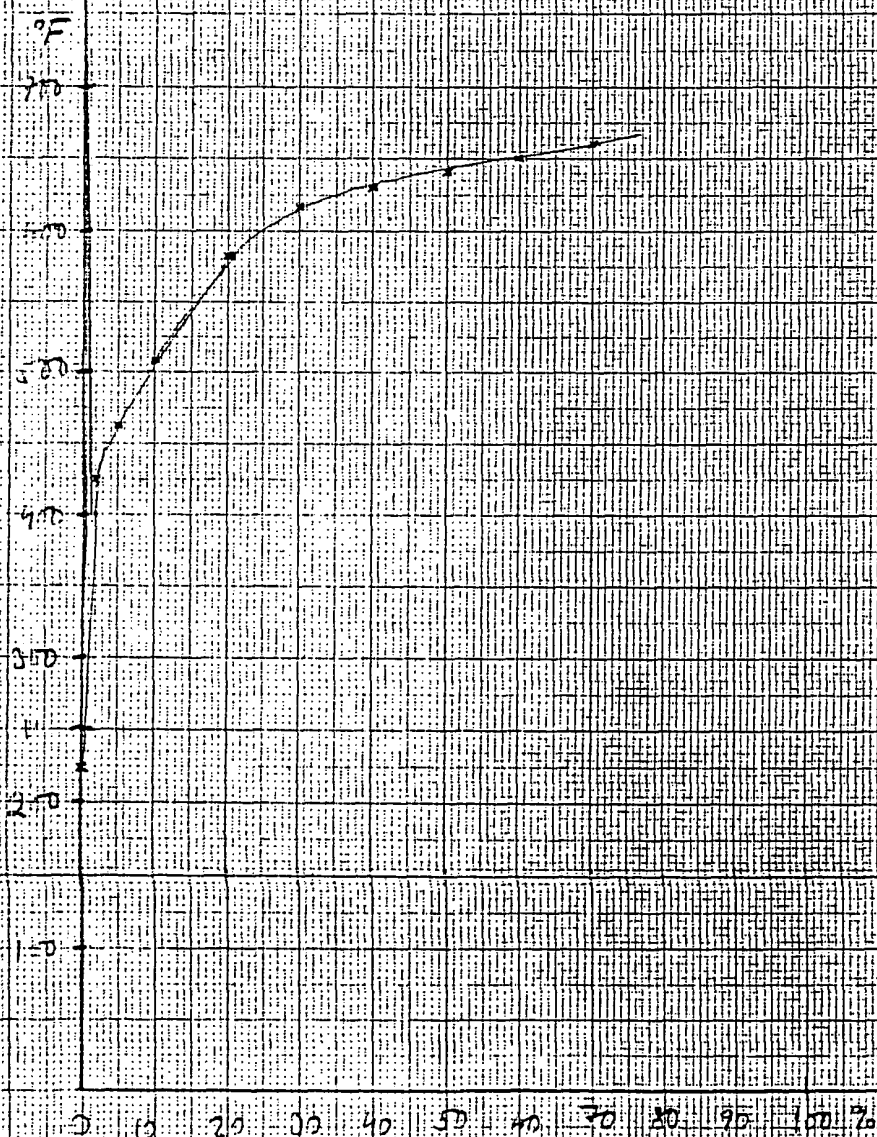
Operation	Recycle gas	Superheated steam	
Crude oil gravity	0,933	0,933	
IBP	250 °F	207 °F	
27.	400	406	
107.	499	504	
377.	657	682	
Crude gas: heating value	350	172	BTU/cu ft.
$H_2$	27,9 %	28,3 %	
$C_n H_m$	13,7	6,1	
$O_2$	—	2,3	
$CO$	25,5	1,1	
$CO_2$	11,3	50,3	
$H_2S$	hace	1,9	
$N_2$ (diff.)	21,6	10,0	
Spent shale: org. content	2-3 %	1 %	

	Low P.	High P.
Fischer assay	21.5	21.5
Residence time	60	40
Temp., retorted shale	915°F	1020°F
Oil yield, % of F. a.	107%	100%
Gas cuft./ton	833	1277
— heating value Btu/cuft	474	340
	} 325.000	
Crude oil: gravity		17.3 API
— gasoline content		17%

### Refining crude shale oil

Process	Charged	Obtained
Atm. distillation	<del>100%</del> crude oil 100%	crude gasoline 6.5%
Visbreaking	crude oil 100%	crude gasoline 9.7%
Recycle cracking	crude oil 100%	crude gasoline 50.3% residue 46.2%
Coking	crude oil 100%	crude gasoline 13.1%
Sulphuric acid treatm. + redist.	crude gasoline 100%	refined gasoline 78.6%

# Distillation curve



14 A4

100E

41



summary of test run (I.S.O. M. Rep. no. 757)

Fischer assay	24.0 gals/ton
Oil yield, % of F. a.	96.1 %
Dry gas	5,305 cuft/ton

Crude oil properties:

Gravity

19.3 °API  
= 0.9383

Gasoline content

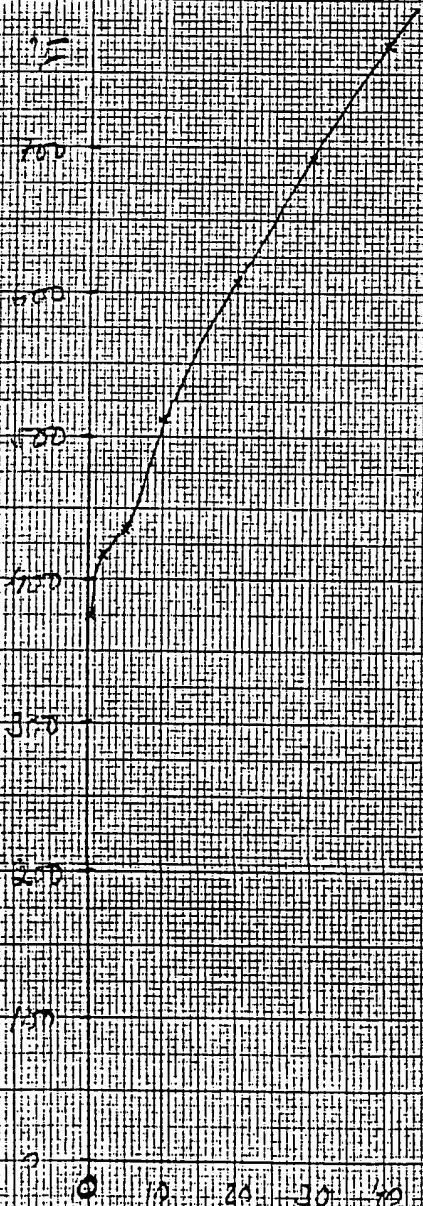
19%

Gas properties:

Gross heating value  
 $N_2 + CO_2$

83 BTU/cu. ft.  
59.2%

# crude oil Distillation curve



514 A 4

SELTE

441

Övarings. Johansson

C.A. NORRMAN CO.

December 12, 1951

, Sweden,

January 14, 1952.

Arende:

MEDDELANDE



Red

Nr

Blad nr

Datum

4/7 1952

Avsändare (evd. + namn + korresp. sign.)

VD/MD

Till

Direktör Wibergh

Jag har här gjort upp ett PM av mera officiell art och ett med mera interna synpunkter, som kanske kan tjäna till underlag för det följebrev som Du lovat att utarbeta till Colorado-rapporten. Skulle man få fram en positiv linje, så kan jag inte se något annat än att man måste följa de tankgångar jag utvecklat i dessa PM. Huruvida vi skola avisera Colorado-gruppen om de resultat, som erhållits vid arbete med Kongo-skiffarna, kan jag i bedöma, men hur som helst ha vi ju åtagit oss att följefölja försöken med Kongo-skiffarna i antydd riktning, och då ligger det ju nära till hands att vi på samma sätt följefölja proven med Colorado-skiffarna.

Om Du anser, att mina synpunkter äro riktiga och kunna tjäna till underlag till följebrevet för Colorado-rapporten, så vore det väl riktigt attända Svenska Maskinverken, direktör Dahlin, en kopia av PM:n. Dahlin är nu hemme.

Hjärtliga hälsningar

tillgivne

Ankomststämpel

H.C. Wibergh

Vice President in Charge of Sales

Kopia till Mr. Carl Norgren,  
Dir. Gejr t, Prof. Schjånberg.

Overing, Johansson

C.A. NORGREN CO.

December 12, 1951

, Sweden,

January 14, 1952.

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
United States Department of the Interior  
Bureau of Mines,  
Box 792, Gräns, Sweden  
R i f l e, Colorado.

U.S.A.

Dear Hads:

I am just in receipt of your letters of the 3rd. Mr. Savage and Mr. Guthrie have been notified by Mr. Vivian that the test will be run in the latter part of January. Mr. Savage is ready with notice. Thank you for your letter of January 11. I note with satisfaction that our sulphur has arrived without any threatening will be breakage. Incidentally, this is the only kind of sulphur that the Swedish authorities presently accept for use in applying your system to the radically different conditions over. It is duly noted that your observer, Mr. Robert Beverly, is designed for the mission in Sweden with arrival in Hallberg about February 1st. We will meet him there and make proper reservation at "Stora Hotellet" in Gräns, your old home, our family for a happy, and prosperous holiday season. I remain

Kindly inform Mr. Beverly that we will try to get in touch with him on his arrival in Stockholm where we presume he will stay at "Grand Hotel". We refrain from making any reservation there in order not to interfere with his plans as being drawn in Rifle.

Carl A. Norgren

Your kind personal regards to several members of the Kværntorp family are forwarded.

Yours very truly,

H.G. Vibergh  
Vice President in Charge of Sales

Kopia till Mr. Carl Norgren,  
Dir. Gejrt, Prof. Schjånberg,

Oyering, Johansson

C.A. NORGREN CO.

December 12, 1951

December 11, 1951

Mr. Hans Wiborgh  
Vice President in Charge of Sales  
Svenska Skifferolje Aktiebolaget  
Drottninggatan 3, Örebro, Sweden

Dear Hans:

I am just in receipt of your letter of the 3rd. Mr. Savage and Mr. Gurthrie have been notified by Mr. Vivian that the test will be run in the latter part of January. Mr. Savage is ready to leave on short notice, and as soon as you have a definite date I am sure it will be taken care of by Mr. Gurthrie.

We appreciate, of course, the manifold problems that you have in applying your system to the radically different shale which we sent over. We are all looking forward with much interest to the result of your larger tests.

With very best regards and good wishes to you and your family for a healthy, happy, and prosperous holiday season, I remain

Sincerely,

Carl  
Carl A. Norgren

CAN:imb

Sweden,  
December 21, 1951.

Mr. Carl A. Horgren, of  
222 Santa Fe Drive, Branch  
Denver 9, Colorado. Interior,  
U.S.A. of Mines,  
Box 737,  
Denver, Colorado.  
U.S.A.

Dear Carl:

This morning we received your cable dated yesterday reading  
as follows:

"PLEASE ADVISE DATE FOR START OF TEST  
GREETINGS  
C A HORGREN CC CARL A HORGREN"

In reply we have already dispatched a telegram establishing  
the start of the test runs to February 1st 1952 or later in your  
decision. I am sorry that we have been still somewhat delayed to  
announce the final time schedule but rebuilding Kvarnatorn more or  
less entirely embeds a heavy stress on everybody, especially our  
production staff.

In reality we will commence charging the Green River shale  
in the HG-retort about January 20 in order to check and evolve  
technical behaviour, heat balances etc. Simultaneously we will  
establish that condensation and control apparatus works smoothly.  
This preliminary test run will be consummated within 6 to 7 days  
and is expressly decided upon to avoid any delay or hook ups  
in the large tests which you will witness and should take place

Concluding the preliminary test run we will shut down the  
retort, cable you before January 26 and await your arrival before  
commencement of the large runs. I hope this procedure will be  
accepted by you people since we owe it to you to eliminate any  
chances of prolonging the actual tests during your visit here by  
neglecting careful and comprehensive planning. On the other side  
this will, of course, result in shutting off part of the HG-unit  
for a considerable time from commercial production but a thorough  
and comprehensive study of the Green River shale is the primary  
object when drafting the schedule.

Enclosed please find one copy of this letter for the event  
you wish to submit the content to Royd Gattis.

Sincerely yours,

Kopia till Ditt. Gejrot, SVENSKA SKIFFEROLJE AKTIEBOLAGET  
Prof. Schjånberg, Schjånberg  
Övering. Johansson.

H.C. Wiborgh  
Vice President in Charge of Sales



ARRIVED  
RECEIVED  
JAN 10 1952  
U.S. DEPARTMENT OF THE INTERIOR  
BUREAU OF MINES

UNITED STATES

Bureau of Mines

Box 792

Sweden,

Rifle, Colorado

November 9, 1951.

January 21, 1952

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
U.S. Department of the Interior,  
Bureau of Mines,  
Box 792, Skövde Aktiebolaget  
R i f l e, Colorado.  
U.S.A., Sweden

Dear Boyd: We will acknowledge receipt of your cable of January 10 that the starting of the final run has been postponed. Your last letter dated October 22 has been filed on my desk for a few days while I was out of town visiting a few points on the West Coast. In order to make comprehensive test runs with the comparatively limited material available we have judged it necessary to erect a special pilot plant for test run purposes. Shutting off a battery or a part of a battery in one of our large commercial units and running your shale here might call for larger quantities than we possess. This advice was arranged as the original

This pilot plant, incidentally attached to one of the wings of Kvarntorp I furnace, is under construction and will probably be ready within three weeks. Another few weeks might be necessary for trimming in the plant. We will then be in the beginning of December with the holidays ahead, will arrive in Hallaberg via Oslo rather late. It is scheduled to arrive in Oslo February 11 and

Therefore, we suggest that the test runs should take place around the middle of January if this would suit you or Mr. Beverly. Within three weeks we will be able to transmit you a detailed schedule of the test runs pending. I hope this will cover your question. One of the members of the so-called Colorado-group, Mr. Frank H. Ricketson, Jr., visited us yesterday and went through our works. He was a very nice gentleman and we had a very interesting conversation while demonstrating Kvarntorp. I told him that we all here certainly would appreciate you visiting us in connection with the test runs and I would not be surprised if he contacted you when returning home to Denver.

Sincerely yours,  
BOYD GUTHRIE, Chief

Oil-Shale Demonstration Branch

Copy: Mr. Carl Norgren,  
Denver.  
Dir. Gejrot, Prof. Schjånberg,  
Övering. Johansson.

1101. G. J. Johansson,  
Öv ring. Johansson,  
Ing. SALOMONSSON.

UNITED STATES

DEPARTMENT OF THE INTERIOR

Bureau of Mines

Box 792

Rifle, Colorado

January 23, 1952

Air Mail

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggatan 3  
Orebro, Sweden

Dear Hans:

This will acknowledge receipt of your cable of January 19 advising that the starting of the final run has been postponed and that our engineer should arrive February 18. I have been awaiting receipt of the letter mentioned in your cable but since it has not arrived, I thought I had better advise you immediately that Mr. Beverly's arrival time at Orebro has been postponed two weeks. He will now arrive in Hallsberg on the afternoon of February 15 rather than February 1.

We had been advised by Mr. Norgren that your research test runs were scheduled to start January 21 and that any time after February 1 you would be in a position to conduct the test for our observer to witness. Thus, because of this advice we arranged the original schedule for Mr. Beverly. I sincerely hope that the test can now be started February 18 as Mr. Beverly has several other commitments in Europe and it is very difficult to make any additional rearrangements of his schedule. When you receive my letter of January 17, be advised that Mr. Beverly will arrive in Hallsberg via Oslo rather than Stockholm. He is scheduled to arrive in Oslo February 14 and spend that night at the Grand Hotel.

Upon receipt of your cable postponing the tests, I contacted Mr. John Savage and he advised me that he would change his reservations so that he would arrive in Hallsberg on February 15. I believe it is his intention to come to Hallsberg from Copenhagen. No doubt he will keep you informed as to his plans.

With kindest personal regards,

Yours truly,

Boyd Guthrie

BOYD GUTHRIE, Chief

Oil-Shale Demonstration Branch

... the all run the Green River shale through one of our retorts shut off and supplied with appropriate condensation for the purpose. This line of procedure will give us the same basic results as working around with the Kvarntorp, Sweden, and will short cut the final evaluation of the shale in retorting systems.

December 3, 1951.

Mr. Carl A. Norgren,  
222 Santa Fe Drive,  
Denver 9, Colorado.

U.S.A. Another staff meeting on December 11th when details of the test will be scheduled. On December 12th I will dispatch this schedule direct to you.

At this time the work would hardly benefit by releasing any report of the laboratory work. Dear Carl: This will all be compiled when the final report is completed.

Thank you for your last letter dated November 27 with a few clippings covering the U.S. synthetic fuel production program. The articles were very interesting. Last Monday we had a staff meeting regarding the development work carried out with the Green River shale. The meeting was attended by Claes Gajrot, Ed. Schjånberg, Arvid Johansson, myself and the project manager in charge of the development work, Dr. G. Salomonsson. A synopsis follows:

- 1) The laboratory tests mainly verify the properties of the shale as presented in the Bureau of Mines literature, with two fundamental exceptions. In the first place the light ends from distillation, i.e. the fractions below 200°C, amount in our analysis to approximately 20% against only a few percent given in the literature. We use, of course, an entirely different retorting method compared to the methods used in U.S.A. In the second place the distilled shale, the coke, seems only to contain about 100 kcal/kg, a figure considerably lower than that earlier suggested.
- 2) Since the basic principle of our retorting methods embraces a strict separation between distillation gases and combustion gases we work with an entirely different heat balance than that applied when treating the shale in, for example, a gas combustion retort. The distillation gases and other organic substances burnt in this retort we aim to utilize for the manufacture of light gasoline, propane, butane etc.
- 3) Due to this somewhat different heat balance equation we work with together with the low calorific value of the coke exhibited, the Kvarntorp retort need to be subject to a series of modifications, the work of which will embrace considerable and time demanding research. Therefore, we aim to approach a somewhat modified alley of scrutinization.

4) We will run the Green River shal through on  
f our HG-retorts shut off and supplied with sepa-  
rate condensation f r the purpos . This line of  
procedure will giv us the same basic results as  
earlier assumed with the Kvarntory method and will  
sh rt out the final valuation of U.S. shale in  
Swedish retorting systems. (JANUARY 1952)

5) The test runs in the HG-retort will take place  
in the third or fourth week in January 1952 if this  
time is convenient for your observers. We will have  
another staff meeting on December 11th when details  
and exact dates of the test will be scheduled. On  
December 12th I will dispatch this schedule direct  
to you.

6) At this time the work would hardly benefit by  
releasing any report of the laboratory work con-  
cluded. This will all be compiled when the final  
test runs are concluded.

I should appreciate it very much if you would dated of  
taking up above mentioned line of action with the Bureau of  
Mines people and present us your opinion. A copy of this letter  
is enclosed if you would prefer to give it to Boyd Guthrie.

With the best regards to all of you, I remain as mentioned  
in his letter and also in an earlier letter direct  
Sincerely yours,

SVENSKA SKIFFEROLJE-AKTIEBOLAGET have your  
Vice President Mr. Savage also as your observer and that he is  
very trusted and will not mislead his mission as your man. In fact,  
Mr. Savage has been told about Mr. Savage and no formal authorisation  
has been received by you on H.O. Wiborgh. He is naturally very  
satisfied but we like to have Vice President in Charge of Sales marking the

With kindest personal regards,

Sincerely yours,

H.C. Wiborgh  
Vice President in Charge  
of Sales

Kopia till Dir ktör Gejr t.,  
Prof. S hjänberg,  
Övering. Johansson.

Sweden,  
January 29, 1952.

Mr. Carl A. Morgren,  
3400 South Elati St.,  
Englewood, Colorado.  
U.S.A.

Dear Carl:

Today I received a letter from Boyd Guthrie dated January 23. Since I do not know whether you have received a copy one is enclosed for your knowledge.

Everything is now arranged for the test runs to start February 18. Mr. John Savage will also witness the test runs as mentioned by Boyd Guthrie in his letter and also in an earlier letter direct from him.

Just for the case of formality we should like to have your verification that Mr. Savage acts as your observer and that he is your trustee and will not misuse his mission as your man. In fact, we have earlier talked about Mr. Savage but no formal authorization has been extended by you or your group. He is naturally very welcome but we like to have all things straight when starting the tests.

With kindest personal regards,  
Sincerely yours,

H.G. Wibergh  
Vice President in Charge  
of Sales

Kopia till Dir. G jr t,  
Prof. Schjånberg,  
Övering. Johansson.  
Ing. Salomonsen.

Sincerely yours,  
E. G. Wiborgh  
January 19, 1952.

Mr. Carl A. Norgren,  
3400 South Elati St.,  
Englewood, Colorado.  
U.S.A.

Dear Carl:

In my letter of January 14 I wrote to Mr. Boyd Guthrie under his address in Rifle about Mr. Robert Beverly appointed to witness our test runs with the Green River shale. Mr. Guthrie told me that Mr. Beverly would arrive to us around February 1st.

This morning we had a staff meeting going through the tests pending and the preliminary time schedule pinpointed for the project. Due to several reasons, among them a nasty snow storm during the last week, the reconstruction of the HC-retort set aside for the purpose has been somewhat delayed. The retort will now be ready for preliminary runs around February 1st and Professor Schjånberg and Mr. Johansson need a week or so to trim the retort and accessory installations first with Swedish shale and afterwards with a small quantity of Green River shale.

Therefore, we should be indebted to you if Mr. Beverly would adjourn his visit to February 18 when everything will be ready for him. Of course, we regret this delay but are anxious to have everything settled when he arrives avoiding any unnecessary unproductive days during his visit.

In order to immediately announce this proposition I dispatched today following cable both to you and Mr. Guthrie:

"SEMICOMMERCIAL TEST RUNS COMMENCING FOR  
GENERAL ANALYSIS OWN RESEARCH ABOUT FEBRUARY  
FIRST SUGGEST YOUR SPECIALIST TO WITNESS  
FINAL RUNS ARRIVE HERE FEBRUARY EIGHTEENTH  
LETTER FOLLOWS GREETINGS WIBORGH

SVESKIAB"

A copy of this letter is for the sake of convenience also sent by air mail to Rifle.

Kindly inform us about your opinion regarding the new date of test commencement. Of course, we can accelerate things a few



days if needed but both our research and production department  
have presently so many other programs to conclude that I personally  
have refrained from rushing them too much.

Sincerely yours,

H.C. Wibergh  
Vice President in Charge of Sales

Kopia till ~~Boyd~~ Guthrie,  
Direktör Gejrot,  
Professor Schjånberg,  
Överingenjör Johansson.

, Sweden,

January 29, 1952.

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
United States Department of the Interior  
Bureau of Mines,  
Box 792,  
Rifle, Colorado.

U.S.A.

Dear Boyd:

Today I received with thanks your letter of January 23 and have already filed your earlier letter dated January 17 regarding Mr. Beverly's Swedish itinerary. Following is noted.

1) Mr. Beverly will arrive in Hallaberg on the afternoon Friday February 15. Since there are several train connections between Oslo and Hallaberg kindly ask Mr. Beverly to send us a cable from Oslo stating which train he arrives on.

2) Mr. John Savage will also arrive in Hallaberg on the same date as Mr. Beverly, probably from Copenhagen. Kindly also advise Mr. Savage that we would appreciate to obtain a cable from him regarding his train schedule.

3) We will meet the two gentlemen in Hallaberg and have booked two single rooms at "Stora Hotellet" in Örebro. Of course, we will also see to it that they will have a nice visit in Sweden.

To-morrow January 30 we will start charging the HC-retort prepared for the test runs with Swedish shale following up this operation in next week by charging Green River shale as formerly advised. Everything will be ready for the test runs to be witnessed when your observers arrive. Since February 16 is a Saturday this day may be spent for a general inspection of our activities. In consequence we rest assured that Mr. Beverly without any difficulties can attend his other commitments in Europe.

All here are naturally sorry that you could not arrange to come over yourself. However, as it is intended these pending test runs will probably be followed by several discussions and negotiations and then I hope we meet in person again.

With kindest personal regards,

Yours till Dir. Gejrot,  
Prof. Schjånb erg,  
Övering. Johansson  
Ing. Salomonsson.

Sincerely yours,

H.C. Wiborgh

Vice President in Charge of Sales

Copy to: Mr. Carl A. Horgren.

COLORADO  
ROAN CREEK QUADRANGLE

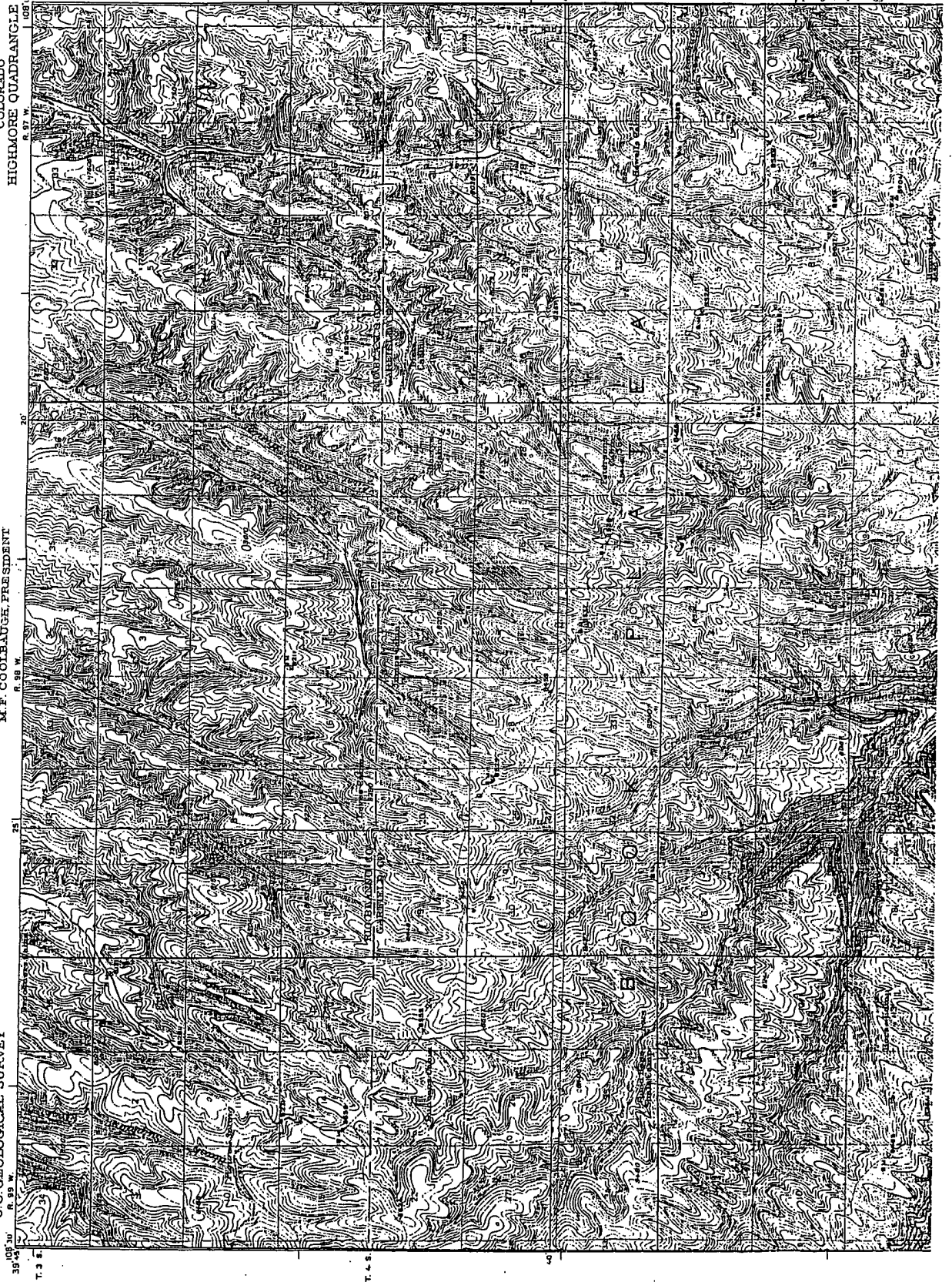


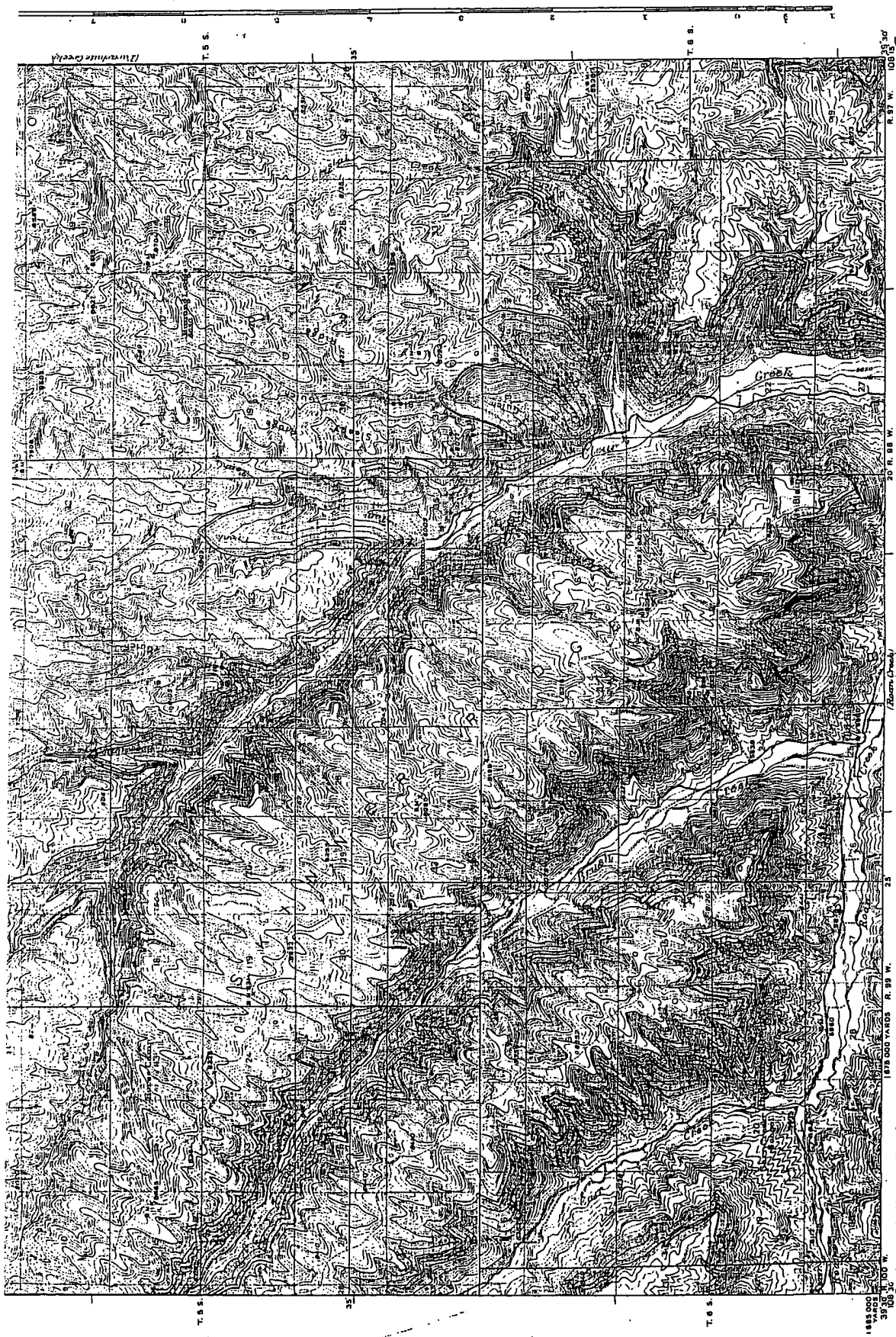


DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY

STATE OF COLORADO  
CLARENCE J. MOSELEY, GOVERNOR  
SCHOOL OF MINES  
M.F. COOLBAUGH, PRESIDENT

COLORADO  
HIGHMORE QUADRANGLE





Topographic projection, North American datum  
5000 yard grid based upon U.S. zone 14, 1983

20 ft. 618 W.

Scale 1:50,000

1875 000 YARDS R. 89 W.

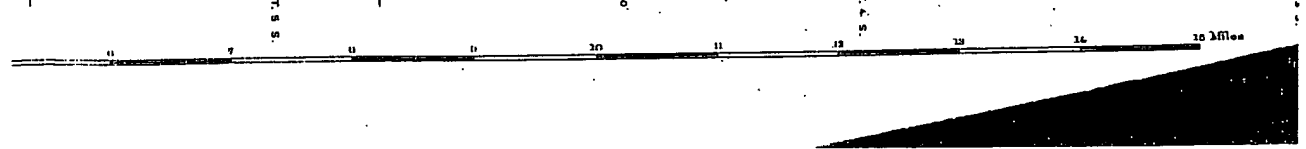
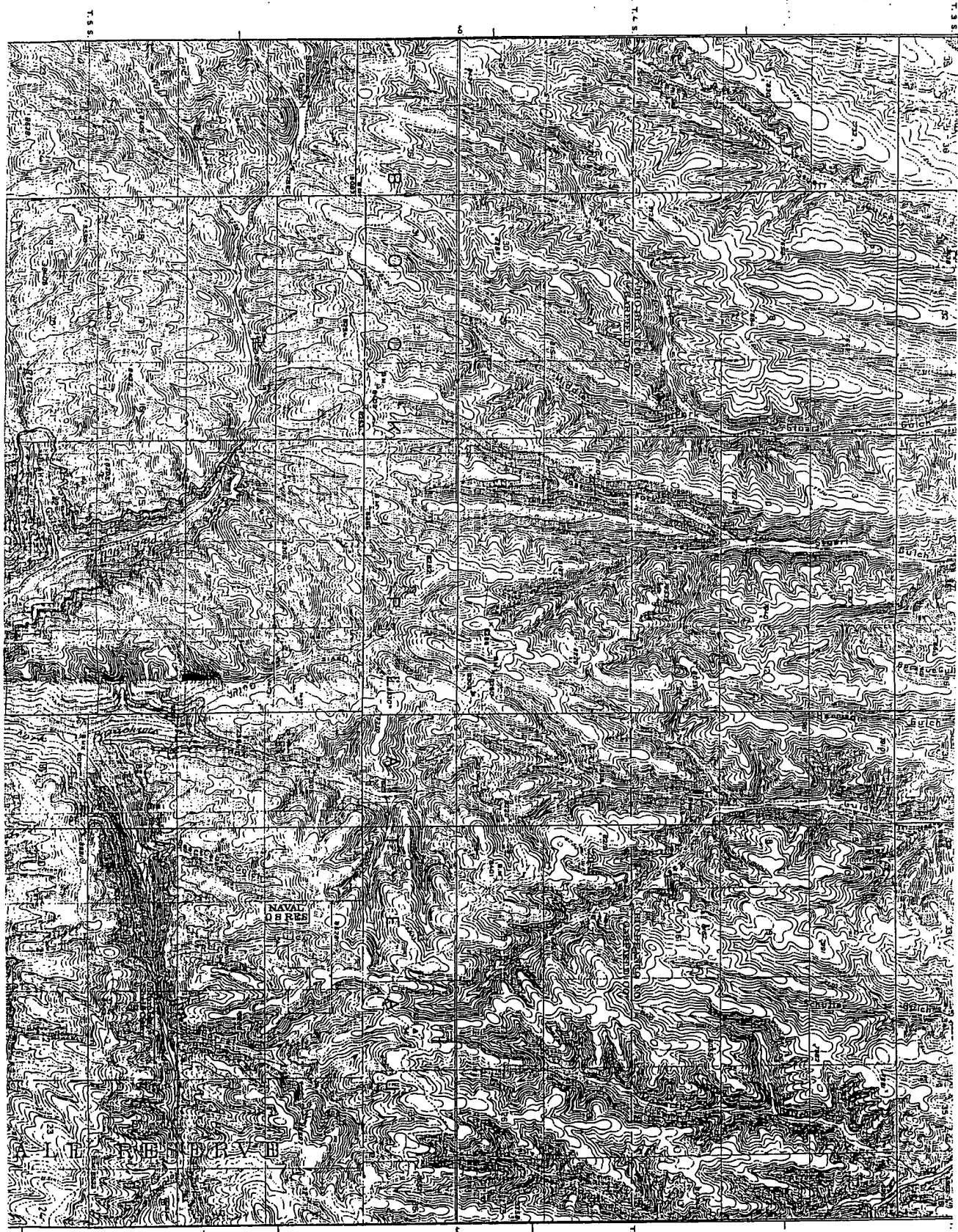
Topography by W.J. Lloyd and Max J. Giesener  
Control by U.S. Geological Survey  
Surveyed in 1976

1875 000 YARDS R. 89 W.

HIGHMORE, COLO.  
Edition of 1976

Contours interval 50 feet  
Datum is mean sea level







Beträffande report on the testing of Colorado Oil Shale in the HG-retort at Kvarntorp, Sweden, daterad den 17/5 1952.

---

Delgives: Direktör Wiborgh  
Professor Schjånberg  
Eventuellt Svenska Maskinverken

Huvudprincipen vid samtliga pyrolysisprocesser i Kvarntorp är, att värmen tillföres skiffern indirekt via en retortvägg och icke så, som i de flesta andra fall tillämpas, genom en direkt beröring mellan skiffern och ett värmeavgivande medium, exempelvis förbränningsgaser. Den pyrolysisprocess, som utarbetats här, den s.k. Kvarntorpsmetoden, grundar sig på att kolet i den efter pyrolysen kvarstående skifferkoksen förbrännes. Den värme, som härvid uppstår, tillvaratages dels i form av ånga, som genereras i ett vattengenomdrivet tubsystem "La Mont", inbyggt direkt i härden, och dels i form av heta förbränningsgaser, som på sin väg till skorstenen får omspola retortrår, fyllda med skiffer, som på så sätt upphettas till pyrolystemperatur. Den svenska skiffern ger efter pyrolysis en koks med ett bundet värmeinnehåll av ca 1000 kcal pr kg.

Då Colorado-skiffer, avsedd för prov i Kvarntorp, anlände hit, utfördes först en noggrann laboratorieundersökning av skiffern. Man kunde därvid konstatera, vilket också framgår av den rapport, som nu ligger färdig, att den koks, som återstår efter pyrolysis av Colorado-skiffer, har ett värmevärde på endast ca 100 kcal pr kg, och det stod från början klart, att Kvarntorpsprocessen i oförändrat skick icke kunde komma till användning för denna typ av råmaterial.

För att emellertid kunna fastställa, hur denna skiffer förhåller sig vid indirekt upphettning, beslöts, att skiffern skulle underkastas prov i en annan typ av retortrår, den s.k. Rockesholmsretortern, som även kommit till tillämpning i full industriell skala i Kvarntorp. Skiffern tillföres även här en retort, som upphettas utifrån på så sätt, att icke kondenserbara pyrolysgaser eller vanlig generatorgas få förbrännas i nederändan av retortern och förbränningsgaserna sedan cirkulera runt retortern,

den / 19

Från VD

innan de föras till skorstenen. Den bifogade rapporten behandlar noggrannt resultaten av de prov, som så utfördes.

Den väsentliga slutsats, som man kan draga av de så erhållna försöksresultaten, är att man får en helt annan och gynnsammare oljekvalitet än vad som är möjligt att erhålla vid den förut omnämnda direkta upphettningen enligt exempelvis Union Oil Company's pyrolysmetod. Vid våra försök erhöles vi i vissa fall ända till 24 volymprocent bensin. Då uppgifter, hämtade från försök vid direkt upphettning, visa en bensinhalt av 1 - 2 volymprocent, skulle man vara benägen att tro, att vid sistnämnda förfarande bensinen förstöres vid processen och att det följaktligen borde vara möjligt att totalt erhålla ett betydligt bättre utbyte av råolja vid av oss tillämpade förfaranden än t.ex. vid Union Oil Co:s metod. Givetvis kan polymerisation inträda, vilket skulle betyda, att lätta kolväten, som vid vår process ger bensin, vid direkt upphettning uppträder i form av tyngre kolväten, som icke längre tillhöra bensinfraktionen.

Utbytet av olja vid de här genomförda försöken har varit 53 - 88 %. Då det icke är möjligt att under en försöksperiod på några dagar få samtliga på driften inverkan förhållanden så inreglerade, att bästa möjliga resultat erhålles, förvånar detta varierande resultat icke. Ingen anledning finnes emellertid att antaga, att man vid praktisk långtidsdrift skulle erhålla sämre resultat i fråga om utbytet än vad vi genomsnittligt ha nått fram till här i Kvarntorp för vår svenska skiffer, d.v.s. en utbytessiffra på genomsnittligt ca 90 %.

Det är mycket viktigt, att vi nu genom försöken ha fastställt, att den indirekta upphettningen ger kvalitativa fördelar av mycket stor räckvidd. Om man alltså kan bibehålla den indirekta upphettningen men ändå nå fram till den process, som ur värmebalanssynpunkt och i övrigt i ekonomiskt avseende ger minst samma resultat, som erhålles vid den direkta upphettningemetoden, har man kommit fram till ett förfarande, som bör vara att föredraga framför andra metoder. De årlånga resultat, som nu föreliggande beträffande Kvarntorpsmetoden, visa bestämt, att detta förfarande torde vara det ur ekonomisk synpunkt bästa pyrolysförfarande enligt den indirekta principen, som för närvarande föreligger. Om man alltså kan bibehålla huvudprincipen vid Kvarntorpsmetoden även för Colorado-skiffern, trots detta råmaterials låga värmevärde på koksen, kunde man ha nått fram till något, som väl skulle kunna hävda sig. Vid Kvarntorpsprocessen med vår svenska skiffer som råmaterial ha vi för närvarande ett utbyte av nyttiga kalorier, användbara helt utanför ugnen själv, i förhållande till med skiffern totalt tillförda kalorier av ända till 69 %. Om Colorado-skiffern håller

1305 kcal pr kg och oljeutbytet enligt Fisher-provet är 9,7 %, så erhålles ett oljeutbyte av 85 % av Fisher-provets värde. Den kalorimängd, som erhålles i form av olja är 820 cal pr kg skiffer, vilket utgör 63 % av totalt med skiffern tillförd värme. Detta betyder, att om den icke kondenserbara gasen och koksen utnyttjas för att ge den i härden och utanför härden i Kvarntorps-ugnen erforderliga värmen, så skulle processen bli självbärande. Det är svårt att förstå, att man med något annat förfarande, med direkt eller indirekt upphettning, skulle erhålla en bättre verkningsgrad. Samtidigt skulle man ernå de kvalitativa fördelar, som den indirekta upphettningen ger.

Örebro den 4 juli 1952.

*Olof Gjert*

Branch

INTERNT TILLÄGG TILL PM BETRÄFFANDE COLORADO-RAPPORTEN.

De synpunkter, jag framfört i bifogade PM, basera sig på de erfarenheter, som gjorts med skiffen från Belgiska Kongo. Värmevärdet i koksen från denna skiffer är till storleksordningen ungefär detsamma som i Colorado-skiffen, och det visade sig då, att vid så liten tillblandning som  $12\frac{1}{2}$  % av Kvarntorpskiffer till Kongoskiffer, erhöles sådana fyrar i härden i Kvarntorpsugnen, så att pyrolysen i huvudsak kunde fullföljas. Detta leder till den tankegång, som för övrigt professor Mertens och ingenjör Passéau förfäktade, och som vi också accepterade vid diskussionen med dem här i sammanhang med försöken med Kongo-skiffen, att vårt provblock borde ombyggas så att den icke kondenserbara gasen kunde förbrännas i härden vid ugnen. En ytterligare förbättring skulle kunna erås, om retortarna förlängdes. Detta är nu möjligt att åstadkomma, då vi ha plåterretortrar. Vi lovade att försöka genomföra detta till slutet av oktober och då fortsätta med proven på Kongo-skiffen. Lyckas detta prov, är ju det hela upplagt för ytterligare försök på samma linjer med Colorado-skiffen. Råmaterial finnes här i tillräcklig mängd. Det primära är nu att konstruera fram en lämplig brännare för pyrolysgasen, och förbränningen bör ske så att förbränningsgaserna direkt hjälpa till att upphetta koksen-askan i härden, så att man får ungefär motsvarande förhållanden som nu råda i Kvarntorpsugnarna med vår skiffer. Jag gör samtidigt uppmärksam på den adress, som lämnats på "The 49th Semi-Annual Meeting of the National Petroleum Association, Cleveland, Ohio, April 17, 1952", vilken separat bifogas. Granskar man de kostnadssammanställningar, som gjorts för anläggning och drift med Union Oil CO:s metod, förefaller det åtminstone vid en ytlig bedömning, som om vi skulle kunna ernå minst lika gynnsamma resultat med Kvarntorpsförfarandet.

Örebro den 4 juli 1952.

*Chas. G. Grit*



Ing. John Pettersson, Ing. Eric  
Pettersson, Ing. Astgren

UNITED STATES  
DEPARTMENT OF THE INTERIOR

Rifle

April 4, 1952

Air Mail

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggatan 3  
Örebro, Sweden

Dear Hans:

Today, I received your post card from New York City and was very interested to know that you were in this country. I was disappointed that you were unable to pay us a visit in Rifle, but I will be looking forward to your early return to the States.

Mr. Beverly has told me the interesting details of the tests conducted at Kvarntorp on the Colorado oil shale. He has also told me of the wonderful hospitality shown him while in Sweden. I want to thank you and Dr. Gejrot in particular for your many courtesies and the gratifying cooperation given Mr. Beverly during his visit. As only those of us know, who have had the privilege to visit Sweden, your hospitality is always one of the highlights of such a visit.

Please extend our thanks to Arvid Johansson, Dr. Salomonsson, and Åke Brandberg for their personal assistance with the preparations and the conducting of the tests. I was sorry to hear that Professor Schjanberg was not feeling well at the time. Please extend to him my best regards and I hope he is now in good health.

Also, please thank Dr. Hammar, Mr. Hedbäck, John Pettersson, Eric Pettersson and Åke Astgren for their time and assistance in showing Mr. Beverly your many operations at Kvarntorp. It has been interesting to learn of your improvements and expansions which have taken place since my visit.

It is my hope that in the not-too-distant future I may have the opportunity to return to Europe and spend a time in Sweden.

When you or any other employees at Kvarntorp have an occasion to be in the United States, please accept our standing invitation to come to Rifle and give us an opportunity to repay a small part of your hospitality. We enjoyed Arvid Johansson's visit and hope he had a pleasant journey home.

Yours very truly,

Boyd Guthrie  
BOYD GUTHRIE, Chief  
Oil-Shale Demonstration Branch

32

Övering. Johansson,  
Ing. Salomonsson.

SAVAGE OIL SHALE DEVELOPMENT COMPANY

P.O. Box 112  
De Beque, Colorado

John W. Savage

April 9, 1952

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Drottninggatan 3, Örebro  
Sweden

Dear Hans:

I want to thank you very much for the fine time you showed me in Sweden. Your many thoughtful courtesies and your constant attention not only added to the value of the visit, but also made it an extremely pleasant time.

The first report is finished and distributed. I presume that the "group" will send you a copy. It does not, however, contain anything that you do not know. In comparing distillation curves of shale oils produced by various retorts the HG is far ahead of others. It must be remembered, however, that we must compete with petroleum as well as rival oil shale processes. Also we must compete in dollars and not solely in "quality of oil". Carl Horgren and John Vivian are highly enthusiastic and I have to caution them that much needs to be done before the capital can be acquired for a plant.

Thank you again for the wonderful hospitality in Örebro and please give my warmest regards to your wife and family.

Sincerely yours,

John

John W. Savage

Övering. Johansson,  
Ing. Salomonsson. UNITED STATES

DEPARTMENT OF THE INTERIOR

Bureau of Mines

Box 792

Rifle, Colorado

January 23, 1952

Air Mail

Mr. Hans Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggatan 3  
Orebro, Sweden

Dear Hans:

This will acknowledge receipt of your cable of January 19 advising that the starting of the final run has been postponed and that our engineer should arrive February 18. I have been awaiting receipt of the letter mentioned in your cable but since it has not arrived, I thought I had better advise you immediately that Mr. Beverly's arrival time at Orebro has been postponed two weeks. He will now arrive in Hallsberg on the afternoon of February 15 rather than February 1.

We had been advised by Mr. Norgren that your research test runs were scheduled to start January 21 and that any time after February 1 you would be in a position to conduct the test for our observer to witness. Thus, because of this advice we arranged the original schedule for Mr. Beverly. I sincerely hope that the test can now be started February 18 as Mr. Beverly has several other commitments in Europe and it is very difficult to make any additional rearrangements of his schedule. When you receive my letter of January 17, be advised that Mr. Beverly will arrive in Hallsberg via Oslo rather than Stockholm. He is scheduled to arrive in Oslo February 14 and spend that night at the Grand Hotel.

Upon receipt of your cable postponing the tests, I contacted Mr. John Savage and he advised me that he would change his reservations so that he would arrive in Hallsberg on February 15. I believe it is his intention to come to Hallsberg from Copenhagen. No doubt he will keep you informed as to his plans.

With kindest personal regards,

Yours truly,

Boyd Guthrie  
BOYD GUTHRIE, Chief  
Oil-Shale Demonstration Branch

, Sweden,  
January 29, 1952.

Mr. Carl A. Norgren,  
3400 South Elati St.,  
Englewood, Colorado.  
U.S.A.

Dear Carl:

Today I received a letter from Boyd Guthrie dated January 23. Since I do not know whether you have received a copy one is enclosed for your knowledge.

Everything is now arranged for the test runs to start February 18. Mr. John Savage will also witness the test runs as mentioned by Boyd Guthrie in his letter and also in an earlier letter direct from him.

Just for the case of formality we should like to have your verification that Mr. Savage acts as your observer and that he is your trustee and will not misuse his mission as your man. In fact, we have earlier talked about Mr. Savage but no formal authorization has been extended by you or your group. He is naturally very welcome but we like to have all things straight when starting the tests.

With kindest personal regards,

Sincerely yours,

H.C. Wiborgh  
Vice President in Charge  
of Sales

Kopia till Dir. Gejrot,  
Prof. Schjånberg,  
Övering. Johansson,  
Ing. Salomonsson.

, Sweden,  
January 29, 1952.

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
United States Department of the Interior  
Bureau of Mines,  
Box 792,  
H i f l e, Colorado.  
U.S.A.

Dear Boyd:

Today I received with thanks your letter of January 23 and have already filed your earlier letter dated January 17 regarding Mr. Beverly's Swedish itinerary. Following is noted.

1) Mr. Beverly will arrive in Hallsberg on the afternoon Friday February 15. Since there are several train connections between Oslo and Hallsberg kindly ask Mr. Beverly to send us a cable from Oslo stating which train he arrives on.

2) Mr. John Savage will also arrive in Hallsberg on the same date as Mr. Beverly, probably from Copenhagen. Kindly also advise Mr. Savage that we would appreciate to obtain a cable from him regarding his train schedule.

3) We will meet the two gentlemen in Hallsberg and have booked two single rooms at "Stora Hotellet" in Örebro. Of course, we will also see to it that they will have a nice visit in Sweden.

To-morrow January 30 we will start charging the HG-retort prepared for the test runs with Swedish shale following up this operation in next week by charging Green River shale as formerly advised. Everything will be ready for the test runs to be witnessed when your observers arrive. Since February 16 is a Saturday this day may be spent for a general inspection of our activities. In consequence we rest assured that Mr. Beverly without any difficulties can attend his other commitments in Europe.

All here are naturally sorry that you could not arrange to come over yourself. However, as it is intended these pending test runs will probably be followed by several discussions and negotiations and then I hope we meet in person again.

With kindest personal regards,

Kopia till Dir. Gejrot,  
Prof. Schjånberg,  
Övering. Johansson  
Ing. Salomonsson.

Sincerely yours,

H.C. Wiborgh  
Vice President in Charge of Sales

Copy to: Mr. Carl A. Mоргren.

UNITED STATES  
DEPARTMENT OF THE INTERIOR

Bureau of Mines  
Box 792  
Rifle, Colorado

July 24, 1951

Air Mail

Mr. H.C. Wiborgh  
Svenska Skifferolje Aktiebolaget  
Kvarntorp  
Drottninggatan 3  
Orebro, Sweden

Dear Hans:

I was very pleased to note by your letter of July 18 that you received the copy of Si Klosky and my report on Oil Shale Industries of Europe. It was a rather difficult report to prepare as we did not stay long enough in any one place to get sufficiently acquainted with the details of operations as to do justice to the industry, but I am glad that you appreciated our remarks regarding Swedish operations.

Mr. Carl Norgren has communicated with me several times since his return from Europe but unfortunately I have not yet had an opportunity to visit with him. He did advise that Johannsen was devising a very comprehensive program for the testing of the oil shale which we shipped.

Mr. Norgren has advised that you will probably conduct the tests near October 1. Running the tests any time this Fall will be quite satisfactory as far as we are concerned in having an observer witness the runs. I had hoped that I personally could come to Sweden but it looks as though it will be impossible as at the present time we are designing a large-scale Gas-Combustion retort with a bed area of 60 square feet and anticipated capacity of 300 tons per day. We hope to have the retort under construction during the Fall months and this, plus other commitments, will preclude my making any trip to Sweden.

We are arranging, however, for Robert Beverly, a chemical engineer, who has been working on our project for three years, to witness the tests. He has been working on our pilot plant and large-scale retorts and is well informed in oil shale technology as far as we have developed it on our project. It is our plan to have him go to Sweden by air and since reservations are at times difficult to obtain, I would appreciate it very much if you could give me as much advance information as possible as to the time you anticipate making the tests so that necessary arrangements can be made to expedite Beverly's trip.

He is an exceptionally fine young chap and I know you will like him very well. If there is any information he can give you regarding our operations please feel free to discuss matters with him.



I am attaching herewith a report on the mining, crushing, and sampling of the shale which was shipped to you. This report is for your general information and any further details that you feel you would find of assistance, in planning your operations, let us know and they will be forwarded to you. We made every endeavor to ship a representative sample of Mahogany ledge material as it occurs at our place of mining. The average oil content of this shale is 26.7 gallons per ton. As you know, our deposit is quite stratified and we took every precaution we could to thoroughly blend the shale at 26.7 so no difficulty would be experienced in its retorting due to variation of the different beds which compose the 70' strata.

Yours very truly,

Boyd Guthrie

BOYD GUTHRIE

Chief

Oil-Shale Demonstration Branch

Copy to: C.A. Norgren

U. S. A:s skifferhittgänger.

Främst Green River-formationen från mitten av Eocen-tiden. Ca. 16.500 sq. miles i Colorado, Utah, Wyoming. Den rikaste av tillhörande förekomster är Piceance Creek Basin i NV. Colorado, där medelmåttig-heten är ~ 500 feet och medelutbytet ent. Fischer är 15 U.S. gallons/ton. Area: 1000 sq. miles.

Den undre delen av förekomsten, den s.k. ~~Mahogany~~ Mahogany Sedge är 70-110 ft tjock och 1000 sq. miles i utsträckning. Medel-Fischer: ~ 30 gals/ton.

Skifferbrytningen. måste göras ekonomisk. Har studerats ingående. Vid en brytning av 150.000 ton/dag kan skiffer brytas och transporteras till en rebotanläggning för 58 cents/ton. Ytterligare 2,5 cents behövs för allt man skall få 4% på anläggningskostnaderna <sup>för frakt</sup> som rygg till ~ 34.000 000 \$.

Skifferforskning

Resultat från Laramie och Rifle:

- Ca. 500.000 BTU behövs för pyrolys av 1 ton genom-snittlig Colorado-skiffer.
- Oljan olefiner ha raka kedjor
- Oljan innehåller hög halt heterocykliska ä.
- Tjärsyran innehåller fenol, kresoler, ngt xylener <sup>högre</sup>
- Tjärsyran → subst. pyridiner och kinoliner.
- Svartet föreligger huvudsakligen som subst. tiofener
- Goda kristallina och mikrokristallina vägar kunnat

40 ton vadera ha drivits av B.o.M. sedan maj 1947 under olika betingelser. Bästa utbytet 85-90 % av Fischer. Försöken avslutades 1. mars -49. (Hillsvidare).

2) Royker processen: mindre batch unit, ~~§~~ provad ~~den~~ jan.-sept. 1948 av B.o.M. Okondenserbare gas upphettas och cirkuleras genom skifferbädden. Avsett som förförsök till en kontinuerlig reakt.

3) Gas-flow- reakt: Kontinuerlig reakt. B.o.M. Liknar Grand Paroisse. Skiffen (i vertikalt ~~§~~ schakt) förvärmes av räckgasen och pyrolyseras med en horisontell ström av okondenserbare gaser, som värmes genom förbränning av skifferkoksens och cirkuleras.

4) Union Oil's reakt: Samma princip som NTU (inre förbränning) men kontinuerlig. Skiffen inneses av en hydraulisk pickong underifrån genom förvärmings-, pyrolytiska- och förbränningszonerna och askan avskrapas upp till. Luften och gaserna sugas ned genom skiffen och förvärmas densamma, och kondensationen av oljan sker i den kalla skiffen. Drivs av Union oil of California i samarbete med B.o.M.

5) Fluidiserings-metoden. Standard Oil Development Co och B.o.M. Försök i Baton Rouge, La.

6) Thermofoz ~~§~~ processen: Socony-Vacuum Oil Co. Vertikal kontinuerlig reakt i vilken skiffen rinner genom för., pyr.  
Lil

...are också en kompromiss mellan olika krav.  
I västra Colorado är vattenfyllgången knapp och måste  
reserveras för "municipal use". Lämpliga är där endast  
sådana metoder, som ej kräva mycket kyl- o. annat  
vatten.

Det synes vidare vara nödvändigt, att en komplett  
anläggning använder olika reaktor typer för de olika kom-  
ponenterna, eftersom varje reaktor typ arbetar bara med en  
 viss komponent.

### Ekonomi.

B. o. M. uppskattar att olja bör kunna produceras i  
skiffer i närheten av Colorado till ett pris av \$ 2,40/bbl  
i 30 gals/bon - skiffer om man använder NTU- reaktor  
och gör 100.000 bbls/dag. Inkluderar 6 2/3 % avskrivningar  
är, men inte ränta på investeringen.

Socony - Vacuum Oil Co, anger för Thermofo-processen  
under likn. förhållanden \$1.10/barel (excl. byggnad), \$1,20  
/barel (inkl. byggnad).

Den experimentgryva studeras byghingen av skiffen. Berget är mycket fast och tillåter upphugande av stora tunn. Bygning och lastning kan därför ske maskinellt, vilket ger hög avverkning: 100-120 ton / arbete o. skift.

Dessutom en mindre, s.k. selektiv gryva varifrån alla slags skiffar för försöksdrift kan byglas (från 1 till 80 gals / ton).

Genomsnittlig oljehalt i cml. Fischen är ~30 gals / ton och gasutbyte = ~2,5%.

Pyrolys: 2 diskontinuerliga NTU-retorier om vardera en kapacitet av 40 ton. Endast provisoriska (för tillv. av material för oljeundersökning.)

Dessutom ett spec. "pilot-plant" - retorik-lab. Två retoriktyper äro spec. intressanta: den diskontinuerliga Royster-retoriken (även kallad Jodavis-r.) samt den kontinuerliga "gas-flow"-retoriken. I båda fallen sker pyrolysen genom ett inert, i en yttre behållare upphettad gas ledes genom skiffermassan. God värmeförmedling, mindre risk för överhettning. Oljeutbytet: ~110% av Fischen.

Även försöke i Union Oil's retorik i Wilmington Cal., i Standard Oil's "fluid solid"-retorik i Baton Rouge, La., och i B. o. M.'s försöksstation i Golden, Col. i Perry-retoriken.

Forskningslaboratoriet i Laramie.

Skiffaroljesektionen är delad på följ. underavdeln.:  
a) Skiffersammansättning och -val - b) Skiffersammansättning och -val - c) Skiffersammansättning och -val

7. slutgärningsanalys.

I) Biprodukter.

A) Skifferpyrolys och raffinering.

Pyrolysen studerades i en adiabatisk reaktor för best. av värmebehov.

En ny pyrolysmetod studerades (Thermal Solution Method) där skiffen före pyrolysen blandades med gasolja. Totala oljebudet förbättrades, men krackningen av gasolja var så intensiv, att sidan måste tillföras från annat håll, varför processen ansåg mindre lämplig för större drift.

B. Skifferanalys.

Ca 2% bitumen, lösligt i bensol, finns i skiffen, men återstoden, kerogenet, är icke lösligt i några kända lösningsmedel. Om dess natur vet man föga, och de formuler man angivit, ansåg man endast vara arbetshypoteser. Man tänker sig kerogenet bestå av annetterade bensolkäror, liknande chrysen, pyren etc. med relativt långa sidokedjor. (Det bör observeras, att den amerik. skifferoljan håller fasta paraffiner, vilka helt saknas i den sv. skifferoljan.) För renframställning av kerogenet extraherades karbonatet med  $\text{HCl}$ , varefter återstoden anrikades med. sink-float-metoden med bensol- $\text{CCl}_4$ -blandningar, varvid slutligen ett koncentrat med blott 9,2% aska erhöles. På detta boms beständ. " 0 0 1 . 0 0 0 1 . "



följa rätt väl en 1:sta ordningens reaktion. För-  
söksdata ha samlats i kurvor som ge möjlighet  
att beräkna sönderdelningen vid olika temperatur  
och pyrolystid.

## Studier av oljeskiffrar i Rifle, Colorado.

### Inledning:

Vid avresan från Los Angeles österut överenskomas med direktör Linden om ett besök vid Bureau of Mines' experimentanläggning i Rifle, Colorado. Från början avsåg direktör Linden att följa med dit, men han fick förhinder och skrev istället ett introduktionsbrev åt mig till chefen för anläggningen, Mr. Boyd Guthrie. Tyvärr föll det sig så att denne var bortrest vid tiden för mitt besök, men hans assistenter togo väl emot mig och gav mig tillfälle att se allt jag önskade och gav mig många värdefulla upplysningar.

### I: Diskussioner och studier vid besöket.

Besöket ägde rum torsdagen och fredagen den 15 - 16 april, 1948. Anläggningen ligger på en bergssluttning cirka en svensk mil väster om den lilla staden Rifle.

Jag togs emot av Mr. Mull, som är Mr. Guthries assistent och tillika chef för laboratoriet. Han introducerade mig för Mr. Siprelle, tydligen metotikingeniör för gruvdriften, och även för Mr. Carl Belser, gruvingeniör.

Mr. Mull visade mig omkring på anläggningen, som verkade mycket välskött. Jag fick obehindrat fotografera vad jag ville och här tagit en hel mängd fotos i färg, som i någon mån ger en föreställning om anläggningens detaljer, men framförallt ger en bild av skifferlagrens läge och mäktighet.

Det nya raffinaderiet är man i full gång med att montera, men det torde ännu dröja några månader innan det kan sättas i drift.

Efter en slingrande bilfärd uppför bergssluttningen från retortanläggningen på 1750 m. höjd över havet till gruvan, som ligger på 2500 m. höjd, 7 miles väg från anläggningen, sammanträffade jag med Mr. Belser, som visade mig gruvanläggningen i detalj och gav mig diverse uppgifter om skifferns lagring och egenskaper. Han hjälpte mig även välvilligt med de provstycken av skiffern, som jag sände hem till Sverige.

Efter den andra dagens besök fick jag tillfälle att flyga över området med ett sportplan av typ Cessna, som en farmare i Rifle var vänlig nog att taga mig upp i på en 45 minuters flygning för enbart bensinpriset. Jag tog därvid åtskilliga färgbilder och även en 8 mm smalfilm, i färg, som kommer att överlämnas till Skifferolje A.B.

### II: Synpunkter på skifferlagrens läge och omfattning.

Beträffande diverse data för såväl anläggningen som skiffern, hänvisas till tre tidigare översända artiklar, enligt följande:

- 1) "Oil Shale Resources of Colorado, Utah and Wyoming", by Carl Belser.
- 2) "Oil Shale Processing ....."
- 3) "Oil Shale Mining" by Tell Ertl.

Dessa benämns nedan ref. (1), etc. eller bilaga 1 etc.

Det relativt lilla område, där Colorado, Utah och Wyoming gränsa till varandra och där oljeskifferarna ligga relativt koncentrerade, omfattar så mycket som ungefär 80 % av all oljeskiffer i USA. Skifferarna äro rika jämfört med den svenska skiffern och beräknas innehålla cirka 300 miljarder barrels olja (ung.  $50 \times 10^9 \text{ m}^3$ ), varav 90 % finnes enbart i Coloradoskiffern. (Enligt ref. 1). Dessa siffror äro emellertid osäkra.

De bergmassiv som Green River formationen omfattar utgöra en imponerande anblick och äro onekligen svårtillgängliga i all sin vildhet och brant-het. Skifferlagren skjuta så gott som överallt ut i dagen i de övre delarna av de branta och mångfaldigt förgrenade bergskanarna och det rikaste cirka 150 meter djupa skifferlagret, som är plant skiktat inom stora områden, lutar något mer än  $1^\circ$  nedåt i riktning mot nord-nordöst.

Inom stora områden vid sidan om Parachute Creek (invid vilken försöksanläggningen ligger), finnas skifferlager med en mäktighet om upp till 400 m., dock skiktade i fleraalager med mellanliggande lager av andra bergarter.

Vertikalsektioner i ref.(1) ge en god bild av skifferns skiktning och visar även det oregelbundna täcke av fin grå och brun sandsten, den s.k. "Evacuation Creek", som varierar ganska kraftigt i tjocklek från c:a 200 meter till 0 m. vid området närmast försöksanläggningen. Man ser att det finnes vissa partier, där detta täcke är genombrutet eller ganska tunt, men större delen av arealen är täckt av ett ganska tjockt sandstenstäck.

Emellertid finnas i de ganska vitt förgrenade floddalgångarna, t. ex. i "East Middle Fork, Parachute Creek", ganska stora areor, där skifferns övre skikt ligga helt i dagen och där de rikaste lagren ligga på måttligt djup. Se bifogade tre kartor över områden väster om Rifle, bilagorna 4 - 6. (Dessa ha endast bilagts ex. 1-3 av rapporten). Gruvan ligger alldeles under krönet av de vertikalt stupande skifferlager, som komma ut i dagen och är tämligen svårtillgänglig. Man har byggt en väg, som i skarpvinkliga zick-zack-linjer leder upp till gruvan och är 7 miles lång. Det är mycket besvärligt att ta sig upp på de ovanför gruvan belägna bergformationerna.

En fältdrift däruppe enligt Ljungströmsmetoden skulle innebära ganska stora svårigheter.

### III: Skifferlagrens oljehalt.

Denna anges i USA i gallons per ton, d.v.s. i enheter om 3,785 liter per 2000 pounds. Vid medelvärde å specifika vikten  $\gamma = 2,40$  (som gäller vid 15 gal/ton), motsvarar värdet i gal/ton exakt oljehalten i volymsprocent.

Enligt ref. (1) (bilaga 1), har man i närheten av gruvan c:a 90 m. tjocka lager med över 15 volyms-% olja och c:a 20 m. tjocka lager med över 30 volyms-% olja.

Medelvärde av två provhål ger 110 m. tjockt lager med i medeltal 13,7 volyms-% olja, varav de rikaste lagren med i medeltal 30 volyms-% olja

Äro 25 m. tjocka (invid den s.k. "Mahogany marker"). Dessa äro som ovan nämnts belägna ganska nära markytan i vissa dalgångar. Lokalt i tunna lager kan oljehalten uppnå det fantastiska värdet 60 volyms-% (öfver 80 gal/ton vid spec. vikten 1,6)

#### IV: Skifferns egenskaper, fysikaliska data, m.m.

Egenskaperna hos den ur Coloradoskiffern med hittills använda metoder utvunna oljan behandlas icke här. De kunna studeras i bilaga 8 - 9, som erhållits från Mr. Mull, eller i Bureau of Mines' Bulletin 415: "Studies of Certain Properties of Oil Shale and Shale Oil" av Boyd Guthrie. (Bil. 8-9 har endast bifogats ex. 1 av denna rapport.)

Själva skiffern studerade jag ganska ingående i och utanför gruvan och tog en mängd färgfotos av den.

Färgen är ganska likartad Kvarntorpskifferns, men varierar ganska kraftigt och är som regel ljusare, speciellt där den är i dagen.

Man fick ett bestämt intryck av att denna Coloradoskiffer är fastare, tätare och mindre sprickigt skiktad än Kvarntorpsskiffern. Sålunda föreföllo de flesta lossprängda stycken, som jag såg, att vara mera spaltade vinkelrätt mot skiktriktningen än parallellt med denna. Det var faktiskt svårt att välja ut det provstycke, som jag skickat hem och som har sina största dimensioner i skiktningens plan.

Tätheten visar sig även däri, att man har mycket litet grundvatten i Gruvan.

Några inneslutningar liknande orstenen i Kvarntorp tyckas inte finnas. Brytningen synes dock gå relativt lätt och man räknar med att kunna få ned brytningskostnaden till 50 cents per ton vid stordrift.

#### Fysikaliska data: (och kemiska)

Följande data för skiffern erhöles vid besöket:

#### Skifferns sammansättning enligt Fischeranalys: (vid oljehalt 25-30 gal/ton)

Olja:	26,7 gal/ton,	10,4 vikts-%
Vatten:	3,3	1,4
Resterande skiffer		85,7
Gas + förluster		2,5
Summa		100,0

#### Kemisk sammansättning av rå skiffer (oljahalt enligt ovan)

Ämne nr.	Formel	Procenttal	Ämne nr.	Formel	Procenttal
1	SiO <sub>2</sub>	26,4	11	Fe <sub>2</sub> O <sub>3</sub>	0,35
2	Fe <sub>2</sub> O <sub>3</sub>	2,6	12	V <sub>2</sub> O <sub>5</sub>	0,003
3	Al <sub>2</sub> O <sub>3</sub>	6,6			
4	CaO	17,1		Summa	83,293
5	MgO	5,4		Organisk substans + vatten	16,707
6	SO <sub>3</sub>	0,6			
7	Na <sub>2</sub> O	2,7		Summa	100,0
8	K <sub>2</sub> O	1,0			
9	CO <sub>2</sub>	20,0			
10	N <sub>2</sub>	0,54			

Nr. 1-6 ha bestämts ur aska, nr 7-12 ur rå skiffer.

Oljehalt i gal/ton:    0    10    15    20    30    40    60    80  
 Specifik vikt  $\gamma$  = 2,76 2,53 2,42 2,32 2,16 2,03 1,81 1,6

Skifferns specifika värme vid 77°F.

Oljehalt i gal/ton:    1    10    20    30    40    50    60  
 Spec. värme s kcal/kg °C: 0,21 0,22 0,23 0,24 0,25 0,26 0,27

Generellt gäller formeln:

$$s = 0,172 + (0,067 + 0,00162 \times G) \times T \times 10^{-3} \text{ kcal/kg } ^\circ\text{C},$$

där G = oljehalt i gallons/ton

T = temp. i °F absolut

Vid 30 gal/ton är  $\gamma = 2,16$  och  $s = 0,24$  kcal/kg °C. Detta motsvarar

$S = 2160 \times 0,24 = 520 \text{ kcal/m}^3 \text{ } ^\circ\text{C}$ , d.v.s. något lägre än värdet  
 575 kcal/m<sup>3</sup> °C som gäller för Kvarntorpsskiffern.

Skifferns värmeledningsförmåga: Inga data tillgängliga.

Data för de hemsända skifferproverna:

TVå prover av medelrik och mycket rik skiffer ha av undertecknad  
 sänts från Rifle till Svenska Skifferolje A.B., emballerade i en trälåda.

Det större skifferstycket väger 35 kg och är taget i medelrika lager  
 straxt över mahogany marker och Mr. Carl Belser uppskattar att det håller  
 cirka 25 - 30 gallons olja per ton.

Det mindre stycket väger 5,5 kg och är taget i det rikaste lagret  
 cirka 14 fot under mahogany marker och uppskattas hålla cirka 65 - 70  
 gallons olja per ton.

V: Tillgångar till elenergi.

Enligt uppgift från Mr. Mull finnas följande kraftstationer inom  
 rimligt avstånd från Rifle:

- |   |               |
|---|---------------|
| 1) Hoover Dam, med nuvarande kraftbelopp        | 1.435.000 hkr |
| "    slutligt framtida kraftbelopp              | 1.835.000 hkr |
| 2) Green Mountain, vid Blue River, just utbyggd | 30.000 hkr    |
| 3) Estes (?) P.      (klar 1949)                | 63.000 hkr    |
| 4) Mary's Lake                                  | 11.300 hkr    |
| 5) Glenwood Canyon (Shoshone)                   | 15.000 hkr    |

I Coloradofloden nära Rifle finnas enligt Mr. Mull endast ett par ställen  
 med fördämningar med cirka 2 meters höjdskillnad, där man skulle kunna anlägga  
 mindre kraftstationer. Direktör Linden är emellertid av den åsikten att det  
 finnes stora outnyttjade vattenkrafttillgångar i omgivningarna.

Staten kan leverera kraft till ett pris av c:a 0,25 cent/kWh, men som  
 regel vill man ej åtaga sig distributionen, utan säljer kraften till privata  
 bolag, som tar hand om distributionen och därvid begära c:a 0,8 cent/kWh.

Vid Bureau of Mines försöksanläggning har man för närvarande installerat tre små transformatorer om vardera 500 kW effekt, d.v.s. man har tillgång till endast 1500 kW, som nästan helt utnyttjas för den normala driften.

Det är sålunda tydligt, att för försök i samma storleksordning som Norrtorp I måste en ny kraftledning anläggas. Möjligen kan ett försök i samma storleksklass som det första försöket vid Östersäter genomföras med den nuvarande krafttillgången.

#### VI: Synpunkter på möjligheter till Ljungströmsmetodens tillämpning i Rifle.

Nedan studeras två alternativ, nämligen a) drift i ett ung. 100 m. djupt lager med medelutvinningen 15 gal/ton, och b) drift i ett 20 m. tjockt lager med ung. 30 gal/ton utvinning. (enligt Fischeranalys)

##### a) Skiffer med 15 gal/ton oljehalt (enligt Fischeranalys)

Specifika värmets blir, med  $s = 0,225 \text{ kcal/kg } ^\circ\text{C}$  och  $\gamma = 2,42 \text{ kg/dm}^3$ :

$$S = 2420 \times 0,225 = 550 \text{ kcal/m}^3 ^\circ\text{C}$$

Antag uppvärmning  $380^\circ\text{C}$ . Antag vidare att Fischeranalysens oljehalt reduceras till 75% vid pyrolys in situ.

Antages vidare 10 % förluster på grund av värmeavledning, blir den erforderliga elenergien per  $\text{m}^3$  skiffer, d.v.s. per  $0,75 \times 150$  liter olja som utvinnes,

$$W = 550 \times 380 \times (1/860) \times 1,10 = 270 \text{ kWh/m}^3 \text{ skiffer.}$$

Således blir energibehovet per liter producerad olja

$$W_1 = 270 / 0,75 \times 150 = 2,40 \text{ kWh/liter.}$$

Vid 0,25 cent/kWh motsvarar detta 2,2 öre per liter.

##### b) Skiffer med 30 gal/ton oljehalt. (ung. 300 liter per $\text{m}^3$ skiffer enligt Fischer)

Enligt sid. 4 gäller för denna  $S = 520 \text{ kcal/m}^3 ^\circ\text{C}$ .

Med samma procentuella utvinning 75 % av Fischervärdet, men med något större värmeförluster i det nu betydligt tunnare skifferlagret, förslagsvis 15 %, fås

$$W = 520 \times 380 \times (1/860) \times 1,15 = 265 \text{ kWh/m}^3 \text{ skiffer,}$$

$$\text{och } W_1 = 265 / 0,75 \times 300 = 1,20 \text{ kWh/liter.}$$

d.v.s. energikostnaden blir endast 1,1 öre per liter.

#### Synpunkter på total produktionskostnad.

Ing. Söderbaum har i en utredning av d. 3/5 1948 beräknat kostnaderna för ett fält i Rifle med  $100 \text{ m}^2$  area och 150 m djup, d.v.s. volymen  $15.000 \text{ m}^3$  skiffer.

Värvid har en så låg oljeutvinning som 55 % av Fischeranalysens värde 15 gal/ton antagits. Något optimistiskt, men mera sannolikt är att 75 % kan utvinnas som antagits ovan. (ingen orsten i Coloradoskiffern bl an)

Skifferns specifika värme har vidare satts så högt som till  $750 \text{ kcal/m}^3 ^\circ\text{C}$ , vilket enligt ovan är c:a 35 % för högt.



Vidare har borrhningskostnaden antagits vara tre gånger så hög som vid Morrtorp och elementkostnaden 50% högre.

Trots detta har ingenjör Söderbaum i sin utredning erhållit resultatet att produktionskostnaderna skulle bli  $\text{§ } 2,35/\text{barrel}$  vid 15 gal/ton oljehalt (liksom i alternativ a) ovan)

Härvid har elenergiåtgången, med avdrag för med skiffergas producerad egen elkraft, beräknats till  $1,9 \text{ kWh/liter}$ , att jämföras med värdet enligt alt a) ovan,  $2,40 \text{ kWh/liter}$  utan avdrag för egen elkraft.

Vid alt. a) utan egen elkraft bortfalla tilläggskostnaderna för ångkraftgenereringen och om man räknar med de enligt nämnda alt. antagna något gynnsammare siffrorna för procentuell oljeutvinning och spec. värme, torde oljeproduktionspriset stanna vid c:a  $\text{§ } 2,00$  per barrel, ett värde som undertecknad tidigare uppskattat.

Vid drift enligt alternativ b) med tunnare skifferlager med 30 gal/ton oljehalt, torde priset kunna bli avsevärt lägre, men endast en liten del av hela skifferkroppen utnyttjas därvid och alternativet är därför olämpligt, såvida det icke kan tillämpas i kombination med brytning av skiffern, varvid även de annars mycket oekonomiska borrhålsdjupen kan reduceras till ett minimum.

#### Kombination av brytnings- och Lj-metoden.

Vid den brytning, som nu planeras, har man tänkt sig att spränga ur 75 % av skifferkroppen i relativt grunda horisontella schakt, där man lämnar kvar kvadratiske stödpelare med 50 fots sida.

Man kan eventuellt tänka sig att inne i dessa schakt med sin relativt plana golvyta utföra borrhning nedåt av värme- och gashål och driva av de underliggande lagren med Lj-metoden. Härvid får givetvis speciella rörned-sättningsmetoder tillämpas, (brännsvetsning av korta rördelar eller nedsättning av rör som lindats bockade på trummor) men metoden är fullt tänkbar. Den skulle innebära en fördel därigenom att horisontella utgångsplan för borrhningen åstadkoms och att borrhningen genom tjocka, högt belägna och starkt kuperade sandstenstäckan undviks.

Vissarligen finnas horisontella markplan om 10-20 acres här och var över skiffern, men den ovan skisserade kombinationsmetoden skulle kunna ge en hög utnyttjningsgrad för hela skiffervolymen och ej begränsa Lj-metodens tillämpning till enstaka markpartier. Svårigheter med ventilation inne i schakten förutses emellertid.

#### Förslag till försök i halvstor skala:

Under alla omständigheter torde det vara lättvindigast att göra försök i halvstor skala inne i gruvan. Man har nu brutit ut en stor kammare med höjden 8 m, bredden 15 m och stor längd. Höjden kommer att ökas till 21 m.

I detta gruvschakt bör det kunna gå bra att sätta ned ett mindre antal element och genomföra ett försök i en skala liknande Ostersäterförsöket.

Möjligheter finnas givetvis även till försök i floddalgångar, där skiffern går i dagen och de rika lagren ligga relativt grunt, men en ny kraftledning måste då troligen dragas till försöksplatsen och vidare blir avståndet till Bureau of Mines försöksanläggning med sina tekniska resurser en olägenhet.

#### Diverse data av intresse:

Total råoljeförbrukning inom USA är för närvarande c:a 2.250.000.000 barrels/år  
=  $6 \times 10^6$  barrels/dygn = 4000 gånger totalproduktionen i Kvarntorp vid fulldrift.

De 300 miljarder barrels som uppskattas finnas i Colorado, räcka vid denna förbrukning i 130 år.

Om så mycket som 10 % av denna väldiga oljemängd skulle produceras med Lj-metoden, d.v.s.  $0,6 \times 10^6 \times 159$  liter/dygn =  $4 \times 10^6$  liter/tim, åtgår vid alt. a) enl. ovan, (15 gal/ton oljehalt), den ungefärliga effekten  $2,4 \times 4 \times 10^6 = 10$  miljoner kW, d.v.s. i det närmaste 10 kraftstationer av Hoover Dams kapacitet. Som synes är det tämligen omöjligt att en verkligt betydande del av USA:s oljebehov inom överskådlig framtid skulle kunna framställas med Lj-metoden tillämpad på dessa skifferar, men det är sannolikt att den bättre oljekvalitet, som man kan vänta sig vid denna metod jämfört med retortmetoderna ger den berättigande för vissa speciella behov, då oljeskifferarna måste tillgripas på allvar och i stor skala i USA.

Det är för övrigt även mycket svårt att tänka sig att man med gruvbrytning och retortbehandling av skiffern skall kunna producera ens en liten bräddel av USA:s oljebehov. Raffineringssvårigheterna äro därvid för övrigt mycket stora än så länge.

Elenergi framställd med koleldade ångkraftverk kostar c:a 0,7 cent/kWh

Mr. Mull uppger att i Journal of the Institute of Petroleum, okt. el. nov. 1947, finnes en artikel om Fluid cracking process Applied to Shale Retorting, som är mycket intressant.

Vid kärnbörning för provtagning i enstaka hål anser man att borrhälspriset är \$ 7,50 per fot, ett mycket högt värde.

Linköping, den 27 juni 1948

*Olle Ljungström*  
Olle Ljungström

#### Bilagor:

- 1 - 3: Bureau of Mines Publikationer enligt lista å sid. 1 (endast ex. 1 av rap).
- 4 - 6: 3 kartor över Parachute Creek, Highmore och Roan Creek, Colorado (endast bilagda ex. 1-3 av rapporten)
- 7: Data för Coloradoskiffer
- 8-9: " " " " -olja. } (endast ex. 1 av rap.)
- 10: Färgbilder från Rifle. ( " " )
- 11: 8 mm färgfilm tagen från luften över Rifle. ( " " )

SOURCE: Bureau of Mines, Oil Shale Mine, Arvil Points, Rifle, Colorado.

**FISCHER ASSAY:**

OIL, GAL./TON	26.7
WATER, GAL/TON	3.3
OIL, PERCENT	10.4
WATER, PERCENT	1.4
SPENT SHALE, PERCENT	85.7
GAS PLUS LOSS, PERCENT	2.5
TOTAL	100.0

**COMPOSITION OF RAW SHALE:**

Item	Constituent	Percent
1	$\text{SiO}_2$	26.4
2	$\text{Fe}_2\text{O}_3$	2.6
3	$\text{Al}_2\text{O}_3$	6.6
4	$\text{CaO}$	17.1
5	$\text{MgO}$	5.4
6	$\text{SO}_3$	0.6
7	$\text{H}_2\text{O}$	2.7
8	$\text{K}_2\text{O}$	1.0
9	$\text{CO}_2$	20.0
10	$\text{H}_2$	0.54
11	$\text{P}_2\text{O}_5$	0.35
12	$\text{V}_2\text{O}_5$	0.003
TOTAL ABOVE		83.293
ORGANIC PLUS WATER (BY DIFFERENCE)		16.707
TOTAL		100.0

ITEMS 1 THROUGH 6 DETERMINED ON ASH, CALCULATED TO RAW SHALE, ITEMS 7 THROUGH 12 DETERMINED ON RAW SHALE.

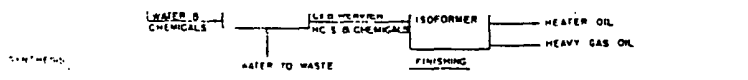


Fig. 2—Synthetic fuels from coal

ained from known United States shale deposits. The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful

Lab. Sample No. Representative Tank Sample Date Analyzed \_\_\_\_\_  
 Source of Shale Demonstration Plant Mine Date Sampled 1/28/48  
 Education Method N-T-U Retorts Education Date \_\_\_\_\_

# SUMMARY OF PROPERTIES

## Properties of Crude Shale Oil

Sp. Gr. 60/60°F. .939  
 A.P.I. Gravity 19.2  
 Sulphur, Percent .8  
 Nitrogen, Percent 1.8  
 Pour Point, °F. 90  
 Viscosity, S.U. \_\_\_\_\_  
 Seconds at 100° \_\_\_\_\_

## Distillation Summary

	Percent	Sp. Gr.	A.P.I.	Temp
Naphtha (Fractions 1-7)	<u>2.9</u>	<u>.839</u>	<u>37.2</u>	<u>-200°</u>
Light Distillate (Fractions 8-11)	<u>14.8</u>	<u>.876</u>	<u>30.0</u>	<u>-310°</u>
Heavy Distillate (Fractions 12-15)	<u>40.1</u>	<u>.925</u>	<u>21.5</u>	<u>-430°</u>
Residuum	<u>39.9</u>	<u>.989</u>	<u>11.6</u>	<u>—</u>
Loss	<u>2.3</u>	<u>—</u>	<u>—</u>	<u>—</u>

# ANALYTICAL DATA

## Distillation at 760 MM. HG. Pressure

Fraction No.	Cut at		Per- cent	Sum Percent	Gravity	
	°C	°F			Sp. Gr. 60/60°F.	A.P.I. 60°F.
1	50	122				
2	75	187				
3	100	212				
4	125	257				
5	150	302				
6	175	347	<u>.8</u>	<u>.8)</u>	<u>.839</u>	<u>37.2</u>
7	200	392	<u>2.1</u>	<u>2.9)</u>		

## Naphtha Composite (Fractions 1-7)

Percent

Tar Acids \_\_\_\_\_  
 Tar Bases Insufficient  
 Neutral Oil Sample  
 Paraffins and \_\_\_\_\_  
 Naphthenes \_\_\_\_\_  
 Olefins \_\_\_\_\_  
 Aromatics\* \_\_\_\_\_  
 \* Including sulphur and nitrogen compounds

## Distillation at MM. HG. Pressure

Fraction No.	Cut at		Per- cent	Sum Percent	Gravity		Viscosity		Aniline Point °C	Cloud Test °F
	°C	°F			Sp. Gr. 60/60°F.	A.P.I. 60°F.	K. V. Centi- Stokes	S.U.V. Sec.		
8	125	257	<u>—</u>	<u>2.9</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>
9	150	302	<u>3.0</u>	<u>5.9</u>	<u>.856</u>	<u>33.8</u>	<u>2.06</u>	<u>32.8</u>	<u>—</u>	<u>—</u>
10	175	347	<u>5.5</u>	<u>11.4</u>	<u>.873</u>	<u>30.6</u>	<u>2.98</u>	<u>36.0</u>	<u>—</u>	<u>—</u>
11	200	392	<u>6.3</u>	<u>17.7</u>	<u>.869</u>	<u>27.7</u>	<u>5.17</u>	<u>42.5</u>	<u>—</u>	<u>—</u>
12	225	437	<u>7.3</u>	<u>25.0</u>	<u>.903</u>	<u>25.2</u>	<u>9.06</u>	<u>55.5</u>	<u>—</u>	<u>—</u>
13	250	482	<u>9.7</u>	<u>34.7</u>	<u>.918</u>	<u>22.6</u>	<u>18.14</u>	<u>89.8</u>	<u>—</u>	<u>—</u>
14	275	527	<u>11.2</u>	<u>45.9</u>	<u>.930</u>	<u>20.6</u>	<u>42.75</u>	<u>197.9</u>	<u>—</u>	<u>—</u>
15	300	572	<u>11.9</u>	<u>57.8</u>	<u>.940</u>	<u>19.0</u>	<u>75.45</u>	<u>348.6</u>	<u>—</u>	<u>—</u>

## RESIDUUM

Carbon Residue of Residuum 9.49 Percent; Carbon Residue of Crude 3.3 Percent  
 Ash on Residuum .07 Percent; Ash on Crude .02 Percent

NOTE: Cuts too dark for aniline point and cloud test.

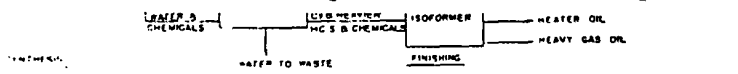


Fig. 2—Synthetic fuels from coal

at least be obtained from known oil shale deposits. The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful

## A.S.T.M. DISTILLATION TEST

DATE 1/28/48SAMPLE NO. Representative Tank Sample

TIME \_\_\_\_\_

SAMPLE SOURCE Grade N-T-U Shale Oil from Tank 515.SUBMITTED BY Transferred to drums on 1/28, 2/3, and 2/6/48

PER CENT	TEMP. °F	Temp. °F (760mm)		
I.B.P.	310	324	GRAVITY	
2	422	438	A.P.I. 60°F	19.2
5	463	479		
10	508	524	Sp. 60/60°F	.939
20	576	594	COLOR	
30	618	636	DOCTOR	
40	640	658	CORROSION	
50	655	673	FLASH 0.0.0.	265°F
60	668	688	R.V.P.	
68	680	700	VIS S.U. @ 210 °F	55 Sec.
80			Pour Point, °F	90
90			% Water	0.5
95				
E. P.			REMARKS	
RECOVERY				
RESIDUE				
LOSS				
BAROMETER	624			
	624 mm. (Avg)			

ANALYZED BY Wood-Shaw

DATE \_\_\_\_\_

APPROVED BY A. S. Houghton

NOTE: Incipient cracking at 680°F/624 mm.

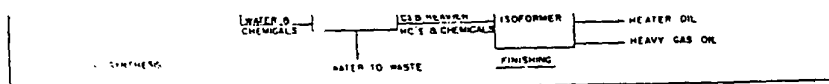
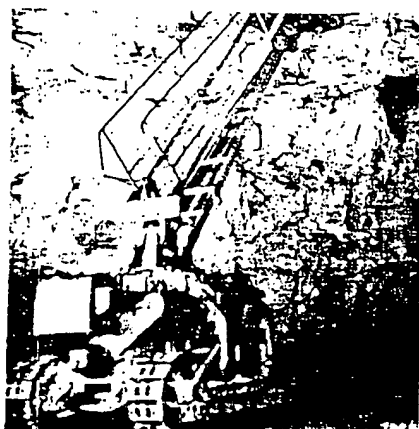


Fig. 2—Synthetic fuels from coal

at least be obtained from known United States shale deposits. The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful



# PRODUCTION OF LIQUID FUELS FROM COAL AND OIL SHALE

by George Roberts, Jr., and Paul R. Schultz

**T**HE three important raw materials that can be used to supplement or replace crude petroleum as sources for liquid fuels are natural gas, oil shale, and coal. Of these, natural gas is the least important because of limited availability. It is finding a profit-

able and essential market as domestic and industrial fuel, and the reserves in excess of these applications could provide only a few per cent of the demand for liquid fuels. Although of minor importance from the standpoint of potential volume, the devel-

opment of synthetic liquid fuels from natural gas has led industrial research efforts in the synthesis field since it appeared to be the most economically attractive of all of the synthesis processes.

Production of liquid fuels from coal and shale has been developed on a commercial scale in numerous foreign countries, particularly Germany. However, the processes as developed abroad are financially unattractive in the American economy, and hence are of little interest in the present discussion. The synthesis of liquid fuels from natural gas has not been practiced in foreign countries, but this process is now nearing commercialization in the United States.

In order to evaluate the comparative economics of liquid fuels from coal and oil shale, it was necessary to postulate representative cases, formulate workable plant designs, and estimate investment and operating costs for each case. Three basic cases were selected, one on oil shale, one on bituminous coal, and one on sub-bituminous coal. Nominal capacity of each plant was fixed at 10,000 bbl. per day. The locations were selected after consideration of the critical economic factors: raw material supply, labor, water, and existing transportation facilities. Final product costs were debited with transportation charges to reflect product distribution in a common market.

The designs were developed on a conservative basis. Known processes of definite operability were utilized to the fullest extent. When proved processes were not available, the results of research were employed to devise a process with maximum assurance of operability.

## Oil Shale

It has been estimated that at least 100 billion barrels of oil can be obtained from known United States shale deposits. The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful

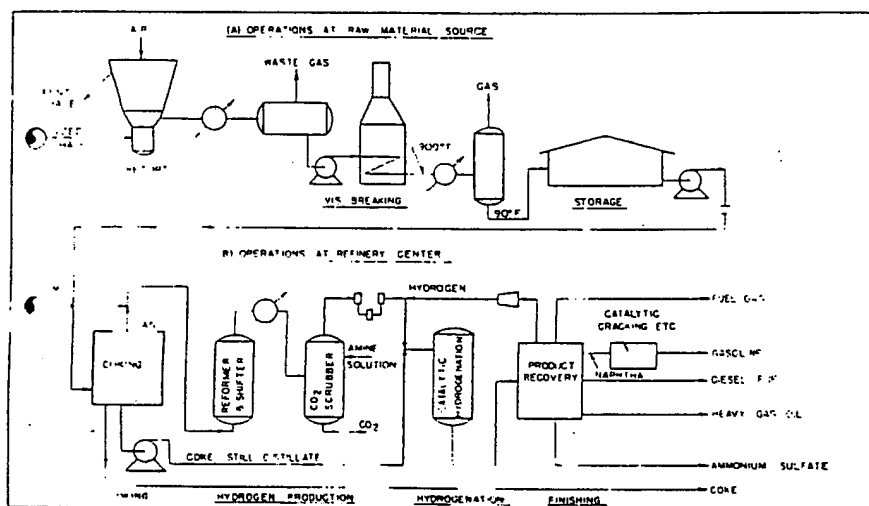


Fig. 1—Liquid fuels from oil shale

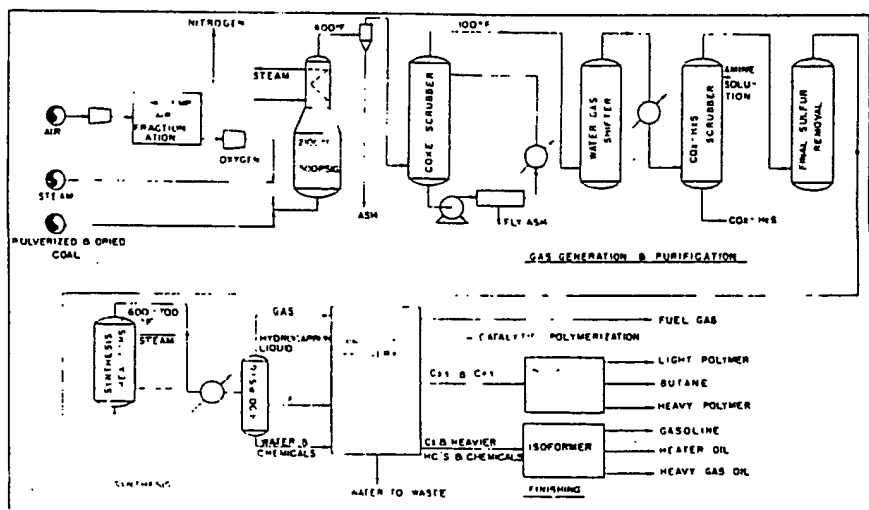


Fig. 2—Synthetic fuels from coal





GEORGE ROBERTS



P. R. SCHULTZ

This paper summarizes the results of a study of the technical and economic status of liquid fuels from oil shale and coal. This study was made to bring up to date evaluations of these raw materials as potential replacements for crude petroleum. Roberts is manager of research department and Schultz is manager of economics department, Stanolind Oil & Gas Co., Tulsa.

as fuels like coal and natural gas.

Production of liquid fuels from oil shale may be divided into two basic operations: (1) the mining of the shale and recovery of the crude shale oil and (2) refining of the crude oil. In the United States, the Bureau of Mines is actively investigating all phases of the operations. Some industrial concerns are studying the retorting operation and refining of the crude oil.

The investigations on mining by the Bureau of Mines at Rifle, Colo., have indicated that oil shale in that region can be mined at a cost of about 60 cents per ton by "underground quarry" techniques. Conventional conveying equipment can be used to transport the shale to the nearby retorting site.

For the retorting of oil shale, several methods have been proposed, and some experimental work has been performed. The methods include N.T.U. retorts, fluid bed operations, Thermoform kiln, and Union Oil Co.'s upflow retort. The Union type was selected as a basis for this study since it is continuous in operation, relatively simple, and requires a minimum of cooling water. It is a large cylindrical vessel into which the crushed shale is introduced by an under feed stoker device. The shale passes upward through the vessel and is discharged as ash at the top. Air enters at the top, is preheated by the effluent ash, burns the residual coke in the spent shale, and carries heat into the raw shale for removing the crude shale oil. The vapors from the distillation zone are cooled while heating the incoming shale, and the make gas and condensed oil are withdrawn near the bottom of the vessel.

Refining of the crude shale oil into products competitive with those from petroleum is a major problem. The shale oil is rich in olefinic and ring compounds and has troublesome con-

TABLE 1—RAW MATERIAL REQUIREMENTS AND PRODUCTS

	Wyoming crude	Natural gas	Oil shale	Indiana bituminous coal	Montana subbituminous coal
Raw material required per barrel of liquid product:					
Crude oil, bbl.	1.22				
Natural gas, M.c.f.		1.10			
Oil shale, tons (30 gal. per ton assay)			1.80		
Coal, tons				0.86	0.90
Liquid-product distribution, per cent:					
Gasoline			46.3	91.4	91.4
Gas oil			48.2	3.3	3.3
Residual fuel			4.5	5.3	5.3
Total	100.0	100.0	100.0	100.0	100.0
Byproducts produced per barrel of liquid product:					
Petroleum coke, bbl. (fuel-oil equivalent)*	0.11		0.09		
Net fuel gas, bbl. (fuel-oil equivalent)*				0.68	
Coal fines, tons				0.10	0.15

\*Based on fuel oil having 150,000 B.t.u. per gallon net heat of combustion.

TABLE 2—INVESTMENT (DOLLARS PER BARREL PER CALENDAR DAY) OF EQUIVALENT GASOLINE

	Wyoming crude	Gulf Coast natural gas	Colorado oil shale	Indiana bituminous coal	Montana subbituminous coal
Producing or mining	\$6,800	\$300	\$1,100	\$1,200	\$1,100
Raw-material transportation		400	1,000	100	2,800
Processing	2,700	5,500	8,200	11,200	11,200
Product transportation				200	800
Operating investment	\$9,500	\$8,200	\$10,300	\$12,700	\$15,900
Housing			1,400	1,200	2,300
Total investment	\$9,500	\$8,200	\$11,700	\$13,900	\$18,200

\*All exploration costs, dry-hole expenses, etc., are charged against crude-oil operations without apportionment to natural-gas operations.

TABLE 3—RAW-MATERIAL COST (OR PRICE) AT MINE OR WELL HEAD

Raw material—	Unit price	Direct costs	Direct costs plus 8% yr. on mining investment for depreciation and interest	Direct costs plus 14% yr. on mining investment (10-year payoff after income taxes)
Wyoming crude	\$/bbl.			
Gulf Coast natural gas	c/M.c.f.			
Colorado oil shale	\$/ton	0.80	0.88	0.99
Indiana bituminous coal	\$/ton	2.54	2.75	3.03
Montana subbituminous coal	\$/ton	1.39	1.58	1.83

\*Market price assumed.

TABLE 4—COST OF LIQUID FUELS EXPRESSED AS CENTS PER GALLON OF EQUIVALENT GASOLINE

	Wyoming crude	Natural gas	Oil shale	Indiana bituminous coal	Montana subbituminous coal
Direct costs:					
Raw material	6.8	3.3	4.1	5.4	3.1
Raw-material transportation	1.4	0	1.8	0.1	0.8
Processing	2.8	4.2	7.0	7.9	7.9
Product transportation	0	2.1	0	0.1	0.4
Subtotal	11.0	9.6	12.9	13.5	12.2
Less byproduct credits	1.3	0	0.5	3.2	0.3
Total direct cost	9.7	9.6	12.4	10.3	11.9
Direct costs plus 6 per cent per year on investment for depreciation and interest	10.7	11.9	16.4	15.3	16.1
Direct costs plus 14 per cent per year on investment (10-year payoff after income taxes)	12.2	15.0	22.5	22.5	27.6

\*Based on market price. †Does not include charges on investment for raw-material production facilities.

TABLE 5—COMPARATIVE ESTIMATES OF LIQUID FUEL COSTS

Raw material Source Company	Natural gas Gulf Coast		Oil shale Colorado		Bituminous coal East of Mississippi River	
	Standard Stanolind Midwest	Standard Oil Dev. Co. East Coast	Standard Stanolind Midwest	Standard Oil Dev. Co. California	Standard Stanolind Midwest	Standard Oil Dev. Co. East Coast
Market Investment per barrel of total product per CD (including raw material and transpor- tation)	\$8.000	\$7.100	\$9.700	\$8.600	\$13.300	\$9.600
Raw-material cost	12c/MSCF		\$0.98/T		\$3.03/T	
Gasoline cost (including 15 per cent charges on investment):						
Raw material, cents per gallon	3.3	3.0	5.1	4.7	6.5	3.7
Manufacturing and transportation less credits, cents per gallon	12.7	10.0	17.4	14.0	16.0	16.0
Total at market center, cents per gallon	15.0	13.0	22.5	18.7	22.5	19.7

\*Data from paper by Murphree, Gohr, and Barr, A.I.Ch.E. regional meeting, Tulsa, May 8, 1949.

lents of nitrogen, sulfur, and oxygen. It is also too deficient in hydrogen to respond well to coking. However, a preliminary coking operation can remove some sulfur with the coke, and the coke still distillate can be hydrogenated to yield a product that is amenable to finishing by conventional methods.

The flow for the shale oil processing is illustrated diagrammatically in Fig. 1. Oil shale, assaying 30 gal. of "oil" per ton, is assumed to be mined in the region near Rifle using the techniques developed by the Bureau of Mines. After crushing at the mine, it is transported by conveyor to a nearby retorting site where the oil content is recovered in Union-type upflow retorts. The crude shale oil is visbroken in order to reduce pour point and viscosity sufficiently to permit pipe-line transportation to a refinery near its potential market. (In this study considered to be Chicago.) Extensive refining near the shale-oil deposits would be impractical because of the unavailability of labor and lack of adequate water supplies.

At the refinery at Chicago the visbroken shale oil is subjected to a preliminary coking operation. The coke still distillate is hydrogenated catalytically, and the resulting product is finished into marketable fuels by conventional refinery techniques. Hydrogen for the hydrogenation operation is obtained by reforming and water-gas shift conversions of the fuel gas produced from the coking and other units.

Process yields and costs associated with recovery and refining of shale oil are discussed under the heading "Economic Comparisons."

#### Coal

For the long-term future, coal is the most important raw material for synthetic fuels. Although the United States coal reserves are probably less than the estimate prepared by the U. S. Geological Survey in 1906, there are undoubtedly tremendous quantities existent. This is particularly true of the lower rank western coals, subbituminous and lignite. Because of their location and their

physical properties, these two grades of coal find little demand today. Certain grades of eastern coal, such as anthracite and the bituminous grade suitable for making metallurgical coke, can be exempted from use for synthetic-fuel production because of their scarcity.

Synthetic liquid fuels can be produced from coal by either the Bergius hydrogenation process or the Fischer-Tropsch synthesis reaction. The data on recent developments in coal hydrogenation are confined primarily to publications of the Bureau of Mines. There has been little published in recent years regarding the work of private industry in this field. Indications are that hydrogenation is somewhat less economical than the Fischer-Tropsch process. Consequently, this discussion will not include coal hydrogenation as a competitive alternate process.

The Fischer-Tropsch process is applicable to either low or natural gas, or any mixture of these two. The fundamental reaction is the conversion of the carbon monoxide and hydrogen gases containing commercial quantities of carbon monoxide and hydrogen into (2) reaction of carbon monoxide and hydrogen to produce a synthetic gas, which is then converted into a hydrocarbon liquid. The hydrocarbon liquid is then refined into the desired fuel products.

The Fischer-Tropsch process is a complex one, involving many steps and many different catalysts. The process is currently being developed by several companies, including the Fischer-Tropsch process, the Bergius process, and the Fischer-Tropsch process. The Fischer-Tropsch process is the most widely used process for the production of synthetic liquid fuels. The process involves the reaction of carbon monoxide and hydrogen to form a synthetic gas, which is then converted into a hydrocarbon liquid. The hydrocarbon liquid is then refined into the desired fuel products.

fiers. The Bureau of Mines is investigating two types of dilute-phase reactors, the simple vortex burner and the Koppers generator. Other groups are investigating fluid-bed carbonization of coal to yield fuel gas and fluid-bed gasification of coal or coke to produce synthesis feed gas. All of these are alternate methods to obtain reaction of coal or coke with oxygen and superheated steam yielding carbon monoxide and hydrogen as primary products.

German commercial practice has been based entirely on low H<sub>2</sub>/CO ratio gas made from coal or coke. The synthesis process typically uses a cobalt-thoria catalyst in fixed beds, with the heat of reaction removed by oil or water circulating through a multitude of tubes traversing the catalyst beds. The chief disadvantages of the German process are (1) low-pressure operation which necessitated large reactor volumes, (2) use of expensive cobalt-thoria catalyst, (3) poor heat removal because of the fixed bed, and (4) the production of a mixture of hydrocarbons having a wide range of boiling points.

In the country work on synthesis of liquid fuels has been carried out primarily by the Bureau of Mines. In their work two types of catalyst have been tested experimentally: a cobalt-thoria catalyst in the fixed bed type, and a catalyst in the fluid bed type. The catalyst in the fluid bed type is fixed bed, and the heat of reaction is removed through the tubes through which the gas passes. The fluid bed type is a fluid bed, and the heat of reaction is removed through the tubes through which the gas passes. The fluid bed type is a fluid bed, and the heat of reaction is removed through the tubes through which the gas passes.

tives, with some waste carbon dioxide and water. The hydrocarbons are recovered by conventional methods. After catalytic treatment under mild cracking conditions (isoforming) which also converts the accompanying oxygenated compounds to olefins, these hydrocarbons are separated into gasoline, distillate fuel, and residual fuel. This synthesis process is conducted at pressures up to 500 psi., has vastly improved heat transfer characteristics as compared to fixed-bed processes, utilizes a cheap catalyst, and produces a high yield of quality gasoline.

Very little work has been done to date on application of fluid-type reactors to low  $H_2:CO$  ratio gas, such as may be obtained from coal gasification. Since the fluid-type reactor is considered superior to the fixed bed for this reaction, it was employed for purposes of this study. As a consequence, the water-gas shift to obtain higher ratio gas was included in the process design and the economics.

Recovery and finishing of the products from the synthesis reaction based on gas from coal have not been intensively investigated in this country. However, the operations developed in connection with synthesis from natural gas should be directly applicable.

The basic process flow for the coal plants is illustrated in Fig. 2, although separate designs were made for the bituminous and subbituminous coal cases. The coal, mined and delivered to the plant site, is pulverized and reacted in a fluid bed with oxygen and steam at elevated pressure. The resultant gas has a  $H_2:CO$  ratio of approximately 0.8 and is reacted with steam over a water-gas shift catalyst to yield a  $H_2:CO$  ratio of 1.8. After removal of carbon dioxide and sulfur compounds, the process flow is similar to that developed for a plant using natural gas. The synthesis gas is reacted over a fluid iron catalyst, and the reaction products are separated. A portion of the off gas is recycled to the reactor while the net make is passed through a conventional oil absorption system to recover the liquid hydrocarbons. The liquid fraction, combined with the debutanized stream from the vapor recovery system, is isoformed to improve octane rating and to convert the oxygenated compounds to the corresponding olefins, and is fractionated into conventional cuts. The propylene and butylene recovered in the absorption system are catalytically polymerized to yield polymer gasoline.

Since this study is concentrated on liquid fuels, neglecting byproduct chemicals, the product water from the reactor is subjected to distillation to concentrate the water-soluble chemicals as a distillate. This frac-

tion is passed through the isoformer to convert the oxygenated materials into olefins and augment the hydrocarbon yields.

#### Economic Comparisons

A study of the economics of liquid fuels from coal and oil shale would have little meaning without an index for comparison. Consequently, a base case for fuels from Wyoming heavy crude was developed. This oil was chosen as the least desirable of current crudes and the first increment of crude production which could be replaced by other sources of liquid fuels. A case utilizing Gulf Coast nat-

ural gas as a synthesis raw material was also developed.

In evaluating these various raw materials as sources for liquid fuels, a number of important factors must be considered. Transportation charges are important in the costs of the finished product, and it was elected to develop cost data for all cases on the basis of a market centered at Chicago.

Choice of raw-material source is likewise of considerable economic significance and was carefully made. Selection of a source of oil shale falls rather obviously to the region near Rifle with the shale-oil refinery located at Chicago as previously men-



*Are your salt water disposal costs too high?*

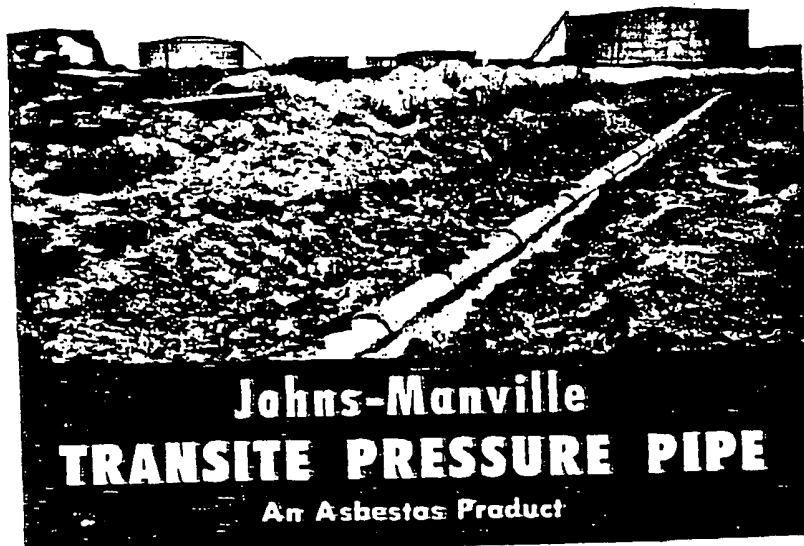
## HERE'S HOW TO CUT PIPE REPLACEMENTS

There's no need to pay out good money for frequent pipe replacements in your salt water disposal lines—not if you put Transite Pipe on the job!

A Johns-Manville trade-marked product, Transite Pipe is made of asbestos and cement combined by a special process that makes it strong, durable and highly resistant to corrosion. It successfully resists the action of salt water on the inside, corrosive soil on the outside, thereby cutting costly pipeline replacements.

You get other advantages, too, with Transite. Light in weight, it is easy to handle. Most sizes can be unloaded and lowered into the trench without mechanical handling equipment. And Transite's factory-made Simplex Couplings speed assembly . . . provide tight yet flexible joints that permit laying the pipe around curves without special fittings.

Get further details about Transite Pipe by writing to Johns-Manville, Box 290, New York 16, N.Y.



**Johns-Manville**  
**TRANSITE PRESSURE PIPE**  
An Asbestos Product

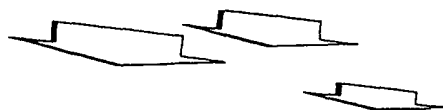
From the standpoint of process design, the principal difference between the subbituminous and bituminous cases is the disposition of make (fuel) gas in excess of plant requirements. In the bituminous coal case, it is assumed that this gas could be marketed in the immediate area (southern Indiana) as industrial fuel. In the subbituminous coal case, no market disposal appeared feasible, so the excess is returned to the synthesis gas generator for reconversion to carbon monoxide and hydrogen. This procedure decreases the coal requirements per barrel of liquid products but does involve reprocessing of synthesized hydrocarbon gases. Another difference in these two cases is that the bituminous-coal case contemplates underground mining while the subbituminous coal case employs strip mining.

Summary material balances for all cases are given in Table 1. It may be noted that the coal requirements per barrel of liquid product are virtually the same for bituminous and sub-bituminous coal. However, the bituminous coal has a net production of byproduct fuel gas amounting to 0.68 bbl. of fuel-oil equivalent. The sub-bituminous-coal case is in fuel balance and does not have this byproduct.

**Investment costs.**—A comparison is given in Table 2. These costs are expressed in dollars per daily barrel of equivalent gasoline. Equivalent gasoline is defined as 100 per cent of the gasoline yield plus 70 per cent of the stillate fuels, plus 40 per cent of the residual fuel. This method adjusts different products to a comparable basis.

**Raw-material costs.**—The comparative costs are given in Table 3. In the costs for shale and coal, all items of expense including management, overhead, royalties, and production and property taxes were considered. The price of \$2.09 per barrel for Wyoming crude is based on a posted price of \$2.04 for 28 A.P.I. gravity and a gathering charge of \$0.05 per barrel. The price of 12 cents per 1,000 cu. ft. for natural gas is representative of the average price which might be obtained under a long-term contract for Gulf Coast natural gas gathered to a

**A MILLION DOLLAR  
INVESTMENT  
PROTECTED WITH**

[illegible]

1A NEW TANK FARM COMPLETED IN 1945

## Why Natasco Products give longer life to tanks

- Let Narasco's years of experience be your guide in proper tank protection. Telephone, call or write for complete information.



**1 2 3**

central point. Although the Bureau of Mines estimate for shale mining amounted to 60 cents per ton, this study yielded 80 cents per ton direct cost and 99 cents per ton with 14 per cent charges on investment.

**Estimated costs of liquid fuels.**—These, as derived from the raw materials discussed, are shown in terms of equivalent gasoline in Table 4. It will be noted that direct costs are separated into several categories. The raw material cost was obtained from the values shown in Table 3. Raw material transportation includes the cost of moving the raw material from a central point at the source to the processing site. For the oil-shale case,

however, the cost of transporting the vis-broken shale oil via pipe line from the retorting site at Rifle to the refinery site at Chicago was included under raw material transportation. Likewise, the raw-material transportation charge for Wyoming crude covers delivery of crude oil via pipe line to a Chicago refinery. In the natural-gas and coal cases, product-transportation costs to the marketing area are included. The byproduct credits include such items as excess fuel gas, petroleum coke, and coal fines.

Charges for depreciation plus interest or return on the investment must be included to ascertain the true

competitive relationship between these sources of liquid fuels. Capital charges at 6 per cent per year (4 per cent depreciation and 2 per cent interest on the borrowed capital) represent a return of investment but nonprofit operation over 25 years. At 14 per cent per year, the profits after income taxes would pay off the investment in about 10 years. It will be noted that the addition of capital charges to the direct costs for coal and shale places the total cost far above the level for Wyoming crude and natural gas. On the other hand synthetic products from natural gas can compete today with products from purchased crude if the competitive marketing area is judiciously selected.

The foregoing discussion is all based on the current technological status of synthetic fuels from coal and shale. Present synthesis developments indicate that several phases of the processes are subject to much improvement. Although it is difficult to evaluate quantitatively the effect of possible improvement on the cost of synthetic fuels, such a computation is desirable to indicate the probable benefits to be derived from future research work. Several process improvements in coal synthesis, such as use of lower  $H_2:CO$  ratio and improved methods of coal gasification, are believed to have an even chance of accomplishment. If all of these improvements can be realized, the cost of equivalent gasoline from Indiana bituminous coal could be reduced from 22.5 to 17 cents per gallon. These costs should be compared with 12.2 cents per gallon for equivalent gasoline from Wyoming crude. Reductions are also possible in the costs of manufacturing liquid fuels from oil shale.

Numerous other estimates of the costs of liquid fuels from sources other than petroleum have been published. Bureau of Mines spokesmen have quoted investments of \$3,100 per daily barrel of capacity from oil shale, \$5,300 per daily barrel from natural gas, and \$8,600 per daily barrel from coal (including mining). Direct comparison of most previously published estimates with those obtained in this study is impossible because the basis and scope of these estimates were not given or were not detailed. However, the results of a similar study by Standard Oil Development Co. were given in sufficient detail to permit a comparison as indicated in Table 5. These data have been adjusted to a common raw-material cost, but charges in investment were unchanged because Standard Oil Development Co. used 15 per cent while, in this study, 1 per cent ad valorem tax had been included in manufacturing costs prior to addition of 14 per cent charges on investment.

For the natural-gas cases, the dif-

*This Year Give*

**World Famous**

**DeLuxe**  
TRADE MARK  
REG. U.S. PAT. OFF.

**FRUIT CAKE**

**Famous  
the  
World  
Over  
For**

*Good  
Taste*

**PRICES INCLUDING MAILING**  
DeLuxe Fruit Cakes are mailed (insured) to any destination in the United States at no extra cost. One to 24 cakes; 2-lbs. \$3.35, 3-lbs. \$4.75, 5-lbs. \$7.50. Write for other prices on quantity lots.



Rich, full-flavored! Delicious! DeLuxe Fruit Cakes are the gift supreme . . . for friends, employees, customers, associates. Only the natural goodness of the world's choicest fruits and nuts, blended by an exclusive recipe, give DeLuxe Fruit Cakes their distinctive flavor and goodness . . . a flavor which has won world renown for more than thirty years.

Solve your gift problems this year the DeLuxe Fruit Cake way! Simply send us your gift list. We'll take care of all details. Mailing, insurance, and gift card included. No extra cost. Send your Christmas shopping worries. And, remember, DeLuxe Fruit Cakes are exclusive gifts. You can give no finer, so tastier, so more timely and appreciated gift than a delicious DeLuxe Fruit Cake. The gift you can't duplicate at any store.

**COLLIN STREET BAKERY**  
CORSIANA, TEXAS

ferences in manufacturing and transportation costs may be due to a combination of the transportation charges to different markets and the crediting of byproducts. For the oil-shale cases, a similar discrepancy may be due, in part, to the same factors.

The bituminous coal estimates show a marked difference in raw material costs. The Stanolind case has a low liquid-product yield. However, it consequently produces a large quantity of byproduct gas which, as a credit, reduces the manufacturing costs. Some portion of the 2.8 cents per gallon difference is attributable to the inefficiency of the Stanolind case introduced by conversion of generator gas to a higher  $H_2CO$  ratio.

In general, the agreement between these estimates is considered to be quite good. The fact that Stanolind estimates are consistently high reflects the basic conservative premise that the designs would incorporate proved processes with a minimum reliance on untested technological improvements. As was previously mentioned, eventual validation of some of these probabilities could reduce the estimated cost of synthetic gasoline from coal from 22.5 to 17 cents per gallon.

In summary, the production of liquid fuels from oil shale or coal is in an immature state of technical development. It can be expected that

continued research will result in process improvements which will effect significant reductions in the investments, operating costs, and raw material requirements involved in synthetic liquid-fuels manufacture.

From the standpoint of economics, this study shows that, at present, liquid fuels from oil shale and coal cannot compete with those derived from crude petroleum. Natural gas as a raw material may or may not be competitive, depending on the relative locations of raw material supply and product markets.

Based only on present technological status and estimated products costs, a choice between coal and oil shale as alternate raw materials for liquid fuels production cannot be made. Future research on these processes, however, should indicate which process is superior.

#### References

1. H. Reed and C. Berg, "The Oil and Gas Journal," 47, No. 34, 111 (1948).
2. U. S. Bureau of Mines, Reports of Investigation (R.I.) 4456, 4457, and 4458, "Synthetic Liquid Fuels," Jan. 1949.
3. H. Reed and C. Berg, "Shale and Air Counter-Flow in New Continuous Retort," Petroleum Processing, 3, No. 12, 1187-92 (1948).
4. J. S. Ball et al., "Composition of Colorado Shale-Oil Naphtha," Ind. Eng. Chem., 41, 581-7 (1949).
5. H. Reed et al., "High Quality Fuels Refined from Oil Retorted from Shale," Petroleum Processing, 4, No. 4, 311-2 (1949).
6. U. S. Bureau of Mines, Information

Circular (I.C.) 7486, "Improvements in Hydrogenation of Coal," Dec. 1948.

7. W. C. Schroeder, "Synthetic Fuel Plants," presented before Petroleum Mechanical Engineering Conference, A.S.M.E. Amarillo, Tex., Oct. 6, 1948.

8. E. V. Murphree et al., "Liquid Fuels for Energy Supply," presented before A.I.Ch.E. regional meeting, May 9, 1949.

## BOOKS

**THE PETROLEUM CHEMICALS INDUSTRY.** By Richard Frank Goldstein. With a foreword by Prof. Sir Robert Robinson. Published by E. & F. N. Spon, Ltd. 57 Haymarket, S.W.1. London, England. 1949. pp. 33s.

This book has been especially compiled for all those interested in petroleum and its products, in catalysis and catalytic processes, in industrial solvents, and in all branches of the organic chemical industry, particularly those concerned with aliphatic chemicals: for the manufacturer, user, the industrial chemist, chemical consultant and chemical engineer, and in the academic sphere, for both teaching staff and student. Both principle and practice are dealt with and the treatment of the subject matter is comprehensive, ranging from fundamental chemical theory to the application and outlet for the finished product, a consideration which makes it of value also to those responsible for technical and commercial development.

The book is divided into 20 chapters from "The Sources of Petroleum Hydrocarbons" to "Chemical Byproducts in Petroleum Refining," those in between having such headings as Oxidation of Paraffins; Manufacture of Olefins; Acids, Anhydrides, and Esters, etc. Three appendices deal with routes to petroleum chemical statistics of production and consumption of petroleum, and statistics of United States production of synthetic organic chemicals of non-coal-tar origin.

## Coring Combination!

**DIAMOND**  
*Truco*  
**BITS**



**D & S** CORE BARREL

**Cores for less!**

**Cut full hole for less!**

Write for free Manual

**Drilling & Service, Inc.**

1011 Elm Street  
Riverside 6811

Dallas 1, Texas  
Tremont 7-5559

Branches: 6724 - Lindsay, Okla. 255  
7239 - Norman, Okla. 4360  
7239 - Shreveport, La. 78527  
through Oklahoma City  
6724 - Tulsa, Okla. 21445



"That's a lotta baloney: bulls ain't attracted by a red shirt like I got on!"

, Sweden,

August 2, 1951.

Mr. Boyd Guthrie, Chief  
Oil-Shale Demonstration Branch,  
United States Department of the Interior  
Bureau of Mines,  
Box 792,  
Rifle, Colorado.  
U.S.A.

Dear Boyd Guthrie:

Thank you for your letter dated July 24 pertaining to the cooperate program presently on schedule.

I myself and in fact all of us had hoped that you or Simon Klosky would have a chance to visit Sweden in order to witness the final part of the test runs. Of course, Mr. Robert Beverly is very welcome and we will not hesitate to present him all details and figures demanded. We believe that the test runs pending will be of decisive importance for a comprehensive evaluation of our methods. Therefore, we hope that you will have a chance to participate at least in the final stage of the tests and would appreciate if you later on would investigate the possibility. Anyway, the preliminary research work will take some time and would hardly demand the presence of your observers. We have to compile several sets of heat balances before we are ready to go into action.

Our research department and our associates are already involved in preparation work. Your gas combustion retort presents fine efficiency figures and your present retort to be designed with a bed area of 60 square feet and an anticipated capacity of 300 tons per day is really something.

In order to establish a smooth road of operation we will within shortly arrange for a test run schedule with the different phases timed and specified. This schedule will be submitted to you and all arrangements for the American expert's visit to Sweden will be properly taken care of.

Kindly accept our thanks for your report regarding the shale shipped to us. Your method of sampling seems to guarantee a representative sample of the Mahogany ledge material. Incidentally, it would be extremely interesting to discuss with you the possibility of combining in the Mahogany ledge the destructive methods with the Ljungström process.

A copy of this letter is sent to Mr. C.A. Norgr n.

Yours very truly,

Kopia till Dir. Gajrot,  
Dir. G.W. Anderson,  
Dir. David Dalin,  
Prof. C. Ljungström.



Till Bolagsledningen.

PM

betr. Bradford- och Canada-projektet.

I januari 1948 uppdrogs åt mig att studera förutsättningarna för tillämpningen av Ljungströmsmetoden på oljesand i U.S.A., företrädesvis i Bradford, Pa. Av ing. Olle Ljungström erhöll jag dels ett antal prover av oljesand, dels en hel del data av intresse.

Efter att ha företagit de laboratorieundersökningar, som de erhållna proverna gav anledning till och efter att ha genomräknat såväl de tekniska som de ekonomiska förutsättningarna kom jag fram till en uppfattning om projektets möjligheter, som jag framlade i ett antal rapporter och promemorior (OS-5 m.fl.) samt vid de konferenser, som ha hållits tid efter annan i frågan. Min uppfattning, som jag efterhand fått alltmera bestyrkt genom de data om oljesanden, som tid efter annan publiceras i fackpressen, var, att projektet ang Bradfordsanden var "dödfött". Jag vill bara påminna om några fakta, vilkas innebörd kanske bäst framgår vid jämförelse med motsvarande för Lj-anläggningen i Norrtorp:

	Norrtorp	Bradford
Oljehalt i lagret	ca. 15 volyms-%	4 volyms-%
Lagertjocklek	16 meter	15 meter
Borrdjup	25 meter	300-500 meter
Kraftpris	(1,3 öre/kWh)	(0,9 cts/kWh)

För jämförelses skull bör naturligtvis nämnas, att man i Bradford blott skulle värma berget 40-60°C mot i Norrtorp 380°C.

Redan de anförda siffrorna ger anledning till betänkligheter i fråga om projektets framtid. Därtill må fogas, att en grundlig teoretisk utredning av strömningsförhållandena i porösa kroppar, som jag gjort, (och som kommer att publiceras i Acta Polytechnica) visar, att det är högst osäkert, om en temperaturhöjning av denna storlek kommer att höja oljeutbytet över vad som kan åstadkommas genom vanlig vattenspolning ("secondary recovery").

På grund av det synnerligen stora intresse, som amerikanska oljekretsar visat för detta uppslag har det ansetts lämpligt att, trots betänkligheterna, ev. utföra ett fältförsök i Bradford för att få ett definitivt svar på frågan om Lj-metodens möjligheter. Ett förslag till fältförsök har därför utarbetats av ing. Olle Ljungström och mig. (OS-12). Detta förslag har översänts till Bradford och är där nu under granskning.

Förslaget utformades försiktigt med tanke på ovan anförda betänkligheter. Den senaste korrespondensen från U.S.A. visar emellertid att detta icke observerats av de amerikanska intressenterna, en följd, som jag fruktar kan få vissa konsekvenser. De förhoppningar, som väckts till liv under ing. Ljungströms besök i Bradford, kommer med all säkerhet icke att infrias, om ett fältförsök utföres där. Den förhands-"goodwill", som nu finnes för Lj-metoden såväl i U.S.A. som i andra länder, skulle helt spolieras av ett fältförsök med negativ utgång. Detta skulle vara till stor nackdel för S.S.A.B., ty Lj-metoden har helt säkert stora möjligheter på andra fyndigheter. En "spelöppning" på den utländska marknaden bör ske på en gynnsam plats, helst på den gynnsamaste, som kan uppletas, och i varje fall icke på en så ogynnsam plats som Bradford.

Under en av de tidigare konferenserna i detta ämne framförde jag förslaget att man borde ägna intresse åt Canadas oljesand- och skifferförekomster. De litteraturstudier, som jag gjort häröver (OS-1) har bekräftat att möjligheterna här är större. Det är ett helt annat material än Bradfordsanden, som är tillfinnandes i Canada. I stället för "oljesand" borde man här använda termen "bituminös sand". Här gäller det icke att öka framrinningen av kapillärt bunden olja, utan i stället att genom en mild upphettning (till ca. 100°C) kemiskt förändra bitumenet, så att en lättflytande olja erhålles. Mängden utvinnbar olja varierar, men uppgår ofta till ca. 30 volyms-%. Topografien är sådan, att stora fyndigheter kunna uppletas, där borrhjupet är ringa.

De tekniska förutsättningarna är sålunda goda. Däremot kan man möjligen hysa någon tvekan om de ekonomiska möjligheterna i Canada just nu, med tanke på de stora mängder fri olja, som under det senaste året upptäckts i samma delar av landet, där också sanden finns. Det synes emellertid av fackpressen att döma vara så, att den bituminösa sanden fortfarande är aktuell. Tidigare har mycket pengar satsats på Max Balls varm-vatten-process, men utan framgång. Nu har man börjat försöka andra metoder. I Chem. Eng. News lästes den 30 jan. i år en notis, som omtalade, att den s.k. "fluid-solid"metoden lagts till grund för en pilot plant, för bearbetning av Alberta-sand.

Ett annat faktum, som må noteras i detta sammanhang är följande: I samband med produktionen av olja i de nya, stora oljefälten erhålles stora kvantiteter naturgas. För transporten av oljan till avsättningsområdena har man redan satt igång att bygga en pipe-line från Alberta (Edmonton) till Lake Superior. Gasen kan man däremot ej få avsättning för. Att bygga en gasledning är otänkbart och den lokala industrin är fortfarande alltför obetydlig för att kunna konsumera dessa gaskvantiteter. Utnyttjandet av gasen är därför oljeproducenternas stora bekymmer just nu. Läget kan illustreras med några produktionssiffror för de två år under vilka oljerushen pågick. (Siffrorna hämtade ur Petroleum Times den 10 februari 1950.).

	Alberta		Hela Canada	
	1948	1949	1948	1949
Total prod. av naturgas m.cu.ft.	49,0 milj.	65,9 mil.	58,6 milj.	74,9 milj.
Värde, milj. \$	6,96	3,30	15,63	9,92
Gaspris, cts/m.cu.ft.	14,2	5	26,6	13,2

Gaspriset har sålunda i Alberta sjunkit från 14 till 5 cts/m.cu.ft. på ett år.

Denna utveckling bidrager till möjligheterna att bearbeta Athabasca-sanden. Det bör nämligen ligga nära till hands att använda denna billiga gas som bränsle i ett ångkraftverk, som genererar den för Lj-metoden behövlige el.-energin. Via ångkraftverk + Lj-anläggning skulle sålunda all överskottsgasen från oljefälten bekvämt kunna omvandlas i olja som ju kan transporteras i rörledningen.

Om det sålunda finns all anledning att frånga Bradford-projektet, så finns det lika stor anledning att arbeta på Athabasca-projektet. (Canada är f.ö. en lämplig inkörsport även betr. metodens användning på oljeskiffer. Oljeskiffern i New Brunswick och Nova Scotia börjar bli aktuell).

För att onödig tid ej skall förspillas, föreslår jag därför att arbetet på Canada-projektet intensifieras. Jag vill ingalunda underskatta värdet av att ha Mr. Hans Lundberg som kontaktman, men jag tror, att det bör gå att få fram saken fortare, eftersom ju det hela ändå är en bisyssla för Mr. Lundberg. Jag anser att en direkt kontakt med canadensiska myndigheter och sakkunniga (t.ex. Canadian Geological Survey) skulle vara av stort värde. Lycket av värde skulle säkerligen även stå att vinna genom direkt personlig kontakt.

Då jag ända sedan den dag, då Amerika-projektet började diskuteras, fått mig anförtrott uppgiften att göra de erforderliga experimentella, tekniska och ekonomiska utredningarna, och därvid hunnit bli väl förtrogen med situationen har jag ansett mig böra på detta sätt fremlägga de synpunkter och förslag, som jag anser vara bäst förenliga med vårt företags bästa.

Norrtorp den 27.2.50.

*Cirila Salomonsson*

beträffande den elektrotermiska oljeframställningsmetodens tillämpning  
i U.S.A. och frågor i samband därmed.

Vid sammanträde den 1 mars mellan direktör Gejrot, dr. Ljungström, direktör Wiborgh, Övering, Johansson, civiling. Söderbaum och undertecknad diskuterades de frågor och problemställningar, som kunde tänkas bli aktuella vid tillämpning av "Ljungströmsmetoden" på amerikanska förhållanden. Som resultat av diskussionen beslöts, att de pågående utredningarna skulle fortsättas och att i första hand följande två alternativ skulle undersökas närmare:

- a) möjligheten använda kvarblivande skifferkoksberg som ackumulator för naturgas.
- b) avdrivning av oljan ur "oil sand" på elektrotermisk väg.

Nedan lämnades dels en sammanfattning av de synpunkter, som framkommo vid diskussionen, och dels några orienterande beräkningar, som utförts med ledning av hittills tillgängliga data.

I Gasackumulatorproblemet.

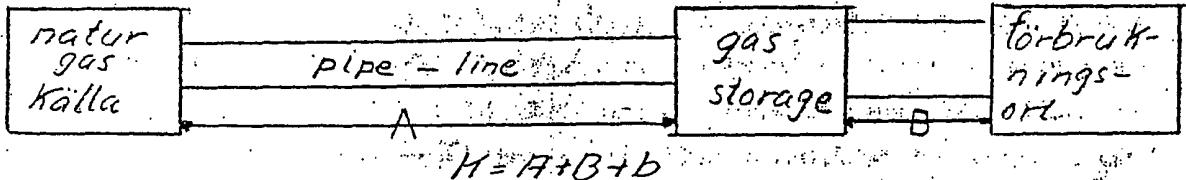
I U.S.A. utgöres en icke obetydlig del av bränsletillgångarna av naturgas. Ehuru mycket bekväm i användningen erbjuder naturgasen vid tillgodogörandet vissa problem i samband med dess transport och lagring. Förbrukningen av gas för såväl hushålls- som industribruk fluktuerar starkt, dels under dygnets olika timmar, dels under de olika årstiderna.

Gasen distribueras från källan till förbrukningsorten genom "pipe-lines" ofta av mycket anseelig längd. För att kunna möta toppbelastningarna måste man emellertid antingen dimensionera rörledningarna för maximalbehovet eller anordna utjämnande gasackumulatorer för förbrukningsorten. Åtminstone vid längre ledningar har man valt det senare alternativet. Som ackumulatorer användes gasklockor av högtrycks- eller lågtryckstyp. Deras i förhållande till kapaciteten höga anskaffningskostnad (jfr nedan) har emellertid i många fall lagt hinder i vägen för naturgasernas utnyttjande.

En annan möjlighet, som på en del orter använts för att ackumulera gas, är att utnyttja gamla, avverkade oljefält. Gas nedtryckes i de gamla borrhålen och lagras i den porösa bergmassan, som förut innehållit petroleum.

Vid elektrotermisk avdrivning av ett skifferfält erhålles som återstod en skifferkoksmassa som dels är hydrofob (vattenavvisande) dels har en aktiv yta, som i kallt tillstånd är i stånd att adsorbera stora mängder av bl.a. kolvätegasar. (jfr. bilaga 1). Det skulle därför kunna vara möjligt att utnyttja ett i närheten av en stad liggande skifferfält för två ändamål, nämligen dels tillgodogörande av olja och gasur skiffern, dels det avdrivna skifferfältets utnyttjande som "gas storage" för naturgas.

För att en dylikkombination skall vara möjlig fordras alltså att i närheten av en stad, som skulle kunna ifrågakomma för naturgastillförsel finnes ett skifferfält, av sådan typ att oljeutvinning kan ifrågakomma. Förhållandena kunna återges med en skiss:



Totala anläggningskostnaden  $K$  för gasens transport (inkl. lagring) från  $a$  till  $c$  blir summan av kostnaderna för rörledningen  $A$  och rörledningen  $B$  samt kostnaden för gasackumulatören  $b$ . Ledningen  $A$  dimensioneras för medelförbrukning av gas, medan ledningen  $B$  dimensioneras för maximalförbrukning.  $B$  blir alltså dyrare pr längdenhet och bör följaktligen göras så kort som möjligt. I det fall, att en gasklocka av vanlig typ bygges kan  $B$  göras praktiskt taget = 0.

I samma mån som gasackumulatören kan erhållas billigare kan naturligtvis sträckan  $B$  få vara längre. Eller med andra ord: Ett lämpligt skifferfält kan utnyttjas som "gas storage" även om det ej ligger omedelbart intill staden.

De fördelar, som stå att vinna genom kombinationen skifferoljeframställning "gas storage" äro:

1) Naturgasens användningsmöjligheter ökas. Orter med skiffertillgångar i närheten kunna använda naturgas, även om avståndet till gaskällan är större än vad som tidigare ansetts ekonomiskt för gasdistribution. Genom att kostnaden  $b$  (jfr ovanst. ekvation) minskas, kan nämligen  $A$  få stiga, utan att den ekonomiska gränsen överskrides.

2) Nya möjligheter öppnas för tillgodogörandet av skifferförekomster som tidigare ansetts stå på gränsen till bearbetbarhet.

Teknisk utformning. Då skifferkoksens adsorptionsförmåga är av betydelse först vid temperaturer omkring  $20-40^{\circ}\text{C}$ , måste berget kylas ned till dessa temperaturer så snabbt som möjligt. Detta bör kunna ske med naturgas som värmetransporterande medium. Samma rör, som användes för bortledning av pyrolysgaserna användes för nedpressning av gasen (i detta skifferkoksbärg). De kvantiteter, som kunna nedpressas, få genast strömma tillbaka upp igen, medförande vissa kvantiteter värme. Gasen får via fältets vanliga kondensorer gå ut i gasdistributionsnätet. På detta sätt kan det valande bergets alltmer tilltagande gasackumuleringskapacitet börja utnyttjas, samtidigt som avkylningen påskyndas. För att erhålla en så stor kapacitet som möjligt bör man kunna förvara gasen under relativt högt tryck t.ex. 20 atm. Detta betyder, att för att tillfredsställa tätning mot läckage skall erhållas, måste skifferkoksen ligga på ett tillräckligt djup 50 meter under markytan eller mera. Detta villkor motverkas dock av kravet på låga borrhäls- och rörkostnader. I varje särskilt fall får en avvägning göras mellan dessa två varandra motverkande faktorer.

Överslagsberäkning. De data och förutsättningar som skulle behövas för en genomräkning av det ovan behandlade projektet saknas, men för att erhålla en uppfattning om vilka storleksordningar det här rör sig om, kan man göra en överslagsräkning med ledning av siffror från svenska förhållanden.

Vi förutsätta att det avdrivna skifferfältet är av samma storlek som det hittills avdrivna Lj-fältet (Norrtorp II) för  $m^3$  skifferberg har därur erhållits ca 90 liter olja +  $100 m^3$  gas. Den köks som kvarstår efter avdrivningen av  $1 m^3$  skifferberg torde innehålla ca.  $0,1 m^3$  fri volym (i form av sprickor o.dyl.). Själva koksvolymen skulle alltså uppgå till  $0,9 m^3$ . Sammanlagda gasvolymen som vid  $20^\circ C$  skulle kunna ackumuleras (o komprimerad och adsorberad form) i  $1 m^3$  skifferberg skulle då bli:

vid 10 atö: ca.  $3,9 m^3$  ( $20^\circ C$ , 1 atm).

Som jämförelse kan nämnas, att vid större storlekar av gasklockor anläggningspriset är ca. 75 - 80 kr per  $m^3$  gasvolym.

Värdet av skifferfältet som gasackumulator skulle då bli:

vid 10 atö gstryck: ca. 290 kr/ $m^3$

Obs! Detta höga värde har ett Lj-fält naturligtvis endast under så gymnsamma omständigheter, att det 100 %igt kan utnyttjas som gasackumulator.

Med nuvarande storlek skulle Lj-fältet motsvara en gasklocka om ca.  $2.000.000 m^3$  ( $20^\circ$ , 1 atm) vid gstrycket 10 atö.

För att utjämna årsvariationerna i gasförbrukningen torde en gasackumulator i en normal stad behöva rymma ca. 1 månads genomsnittsförbrukning. Det nuvarande Lj-fältet skulle alltså kunna utjämna årsvariationerna inom ett distributionssystem med en dygnsförbrukning av ca.  $70.000 m^3$ . Som jämförelse kan nämnas, att Örebro stads ungefärliga förbrukning är  $25.000 m^3$ /dygn.

## II. Oil-sand-problemet.

Problemet att med vattentryck o.dyl. metoder utvinna kvarvarande olja ur "oil-sand" torde vara så väl genomarbetat av amerikanska teknici, att möjligheterna på detta område torde vara uttömda. En möjlighet finnes, att på elektrotermisk väg uppvärma sanden så mycket, att oljans viskositet och ytspänning sänkes, vilket skulle underlätta oljans framrinning till pumphål. Emellertid är sanden så finkorning och följaktligen de kapillära krafterna så stora, att det förefaller föga sannolikt att en dylik sänkning av viskositet och ytspänning skulle kunna frigöra några avsevärda kvantiteter olja.

En annan möjlighet att utnyttja den elektrotermiska metoden består i att sanden upphettas till så hög temperatur (t.ex. ca.  $200^\circ C$ ) att en verklig destillation (ej pyrolys) av i sanden befintliga olja sker. För att avdriva

Även de tyngre oljefraktionerna skulle man vid destillationen tillföra vatten (vattenångdestillation). Detta medför naturligtvis större värmeförbrukning, varför man måste undersöka i varje särskilt fall på vilken punkt destillationen skulle avbrytas, för att optimalt utbyt skulle erhållas.

En fördel med denna metod för bearbetning av oljesand är att även relativt djupt belägna "oil-sand"-förekomster bli åtkomliga för oljeutvinning. Största möjliga arbetsdjupet blir naturligtvis beroende på borrhingskostnaderna och sandens oljehalt och mäktighet.

Överslagsräkning. En grov bild av energiförbrukningen för avdestillationen kan man erhålla genom jämförelse med skifferpyrolys. Oljehalten i oil-sand är varierande, men är ofta av samma storleksordning som i skiffer (5-6 %). Den mineraliska substansens specifika värme i sand och i skiffer är ungefär detsamma. I jämförelse med det värme, som åtgår för den mineraliska substansen temperaturstegring kan oljans ångbildningsvärme, resp. skifferpyrolysens reaktionsvärme försummas (i denna approximativa beräkning). Vid upphettning av skiffern till 400°C utvinnes ca. 2/3 av dess oljehalt och ungefär lika stor del av den i sanden inneslutna oljan torde avdestillera vid sandens upphettning till 200°C. Enligt resonemanget ovan skulle för sandens upphettning till 200°C åtgå ungefär hälften av det värme, som behövs för skiffrens upphettning till 400°C.

Det har vid Lj-fältet visat sig, att energibehovet har uppgått till 5-6 kWh/liter olja. Vid oljeavdrivning ur oljesanden kan man alltså vänta sig en förbrukning av 2,5-3 kWh/liter olja.

#### Sammanfattning.

Tänkbara möjligheter för Ljungströmsmetodens användning i U.S.A. är:

- a) för oljeutvinning ur skiffer.
- b) för kombinationen oljeutvinning-"gas storage".
- c) för avdrivning av restolja i "oil-sand".

#### Aktuella frågor.

För att man skall få en uppfattning om möjligheterna att realisera ovan nämnda projekt måste de naturliga förutsättningarna undersökas. Detta innebär att följande frågor närmare behöva utredas:

1) Förekomsten av oljeskifferar överhuvudtaget. Det är att förmoda att tillgängliga kartor o.dyl. över U.S.A:s oljeskifferar ha utarbetats med hänsynstagande till möjligheterna att bearbeta skifferar enligt tidigare kända metoder. Detta torde medfört att endast i dagen gående eller grunt liggande fyndigheter beaktats. Den elektrotermiska in situ-metoden gör nu även skifferar på större djup bearbetbara. Under förutsättning att borrhaskostnaderna ej bli för höga och att oljeutbytet pr borrhål (dvs. produkten av skifferlagrets mäktighet och oljehalt) är tillräckligt högt, böra skifferar



av ända till 100, kanske 200 met rs djup under markytan kunna bearbetas.

En uppfattning om dylika skifferförekomster bör lämpligen kunna erhållas av en geolog med erfarenhet på området (t.ex. från B.o.M.) Av intresse är sålunda både oljehalt, mäktighet och djup.

2) I synnerhet förekomsten av skifferar i närheten av städer, där naturgastillförseln kan bli aktuell. Därvid bör ihåggas, som ovan påpekats, att räjongen för distribution av naturgas från en gaskälla, kan bli avsevärt utökad genom kombinationen skifferfält-gas storage". Dessa skifferar böra ligga på ej för litet djup och ej för långt bort från staden i fråga. Däremot är kravet på hög oljehalt ej fullt så strängt som vid övriga skifferar.

3) Ett närmare studium av någon befintlig "pipe-line" för naturgas med tillhörande "gas storage" (helst av typen gammalt oljefält) skulle säkerligen vara av värde. Speciellt intresserar då fordringarna på och anordningarna vid en dylik gasackumulator, uppgifter om gasförluster i berget o.dyl.

4) Förekomsten av "oil-sand" som kunna vara lämpliga för elektrotermisk destillation. Även här bör den synpunkten beaktas, att också djupare liggande lager kunna bearbetas, om oljehalten och övriga faktorer äro gynnsamma.

Norrköping den 9.5.1948

Gösta Salomonsson

Vidimeras:

*D. Torken*.....

*M. Andersson*.....

October 31, 1950

Svenska Skifferolje A. B.  
Drottninggatan 5  
Göteborg, Sweden

Attention: Mr. C. A. Moberg, President

Ljungstrom In-Situ Method

Gentlemen:

During the period from Inning September 10th and ending September 19th, 1950, the undersigned and seven additional technical and business experts from the United States of America were privileged to attend certain conferences in Sweden with technical and business experts representing your organization.

The above stated conferences were held through prior mutual agreement for the purpose of aiding interested parties in the United States to determine the feasibility for use of the above named Ljungstrom In-Situ Method, or Electrothermic Process, in the recovery of residual oil reserves from so-called depleted oil fields, such as may be found at, or near, Bradford, McKean County, Pennsylvania, and are particularly known as the "Bradford Oil Field".

The technical experts, who represented a local group of sponsors, have delivered their reports upon the results of their findings. It is the unanimous decision of the technical experts that the Ljungstrom In-Situ Method is uneconomical for use in the recovery of residual oil reserves in the Bradford Oil Field. The

cost of electric energy in the Bradford area at the present time, and in the foreseeable future, is the most effective contributing cause of their decision.

The local group have also advised that they cannot be interested in the recovery of oil from more shallow oil and gas bearing formations or from shale in the United States and Canada through use of the Ljungstrom In-Situ Method, for the same reason that affects its use in the Bradford Oil Field.

You are to be complimented upon your gigantic operation in shale and the success which has been so earnestly achieved. Our best wishes are for your continued success.

During our visit in Sweden, and more particularly at the field demonstrations and technical and business conferences, we were afforded the privilege of acquiring your confidential information, even to the most minute detail. We have treated your information with the absolute confidence in which the same was reposed in us and are assured that we will continue to do so.

Your decision is submitted with my deepest regret and I do want you to know that every possible consideration was given before the said decision was reached. In the event you are ever successful in finding a method whereby economic results may be obtained in the recovery of oil from residual reserves, I shall be pleased to aid in perfecting the same and perpetuating its use.

My sponsors and all who were privileged to attend the conferences and social functions in Sweden join in extending most sincere thanks for the interest you displayed in our problem and for your splendid cooperation.

Very truly yours,

*Victor H. Samuelson*

Victor H. Samuelson

VHS/jt

## SVENSKA SKIFFEROLJE AB, A. S.

The meeting in Sweden was the culmination of efforts extended by the Svenska Skifferolje Aktiebolaget of Gothenburg and Stockholm, Sweden, and Victor L. Samuelson of Bradford, Pennsylvania, in connection with matters of technical import relative to the oil industry.

In Sweden, certain deposits of shale have been operated for the recovery of kerosene and its derivatives since the year 1941 at Varberg in the province of Bohuslän, where the plants of Svenska Skifferolje Aktiebolaget are now located. The stratum of shale is about 50 feet deep and contains kerosene (kerosene) embedded therein varies from 5 to 10 percent by weight and would amount an equivalent percentage of oil. The shale deposits in the area would allow an extensive oil production for centuries to come, according to a published statement by the Swedish Shale Oil Company.

The shale oil industry in Sweden is of gigantic proportions and the operations must be well directed to obtain the success which has been achieved by them. The industry has been maintained for national reasons and for the same purposes. For example, many of the stripper wells in America.

The Bradford oil field, which contains approximately 25,000 productive acres of oil and gas bearing properties, is located principally in McKean County, in the State of Pennsylvania, and the

United States of America. The first producing oil well was discovered about the year 1871 and to December 31, 1949, a total of 523,852,446 barrels of oil had been recovered and produced from this field. A schedule entitled "Bradford Oil Field - Annual Crude Oil Production" is herewith enclosed for the purpose of showing the production of oil throughout the years.

The principal producing formation in the Bradford Oil Field is known as the "Bradford" or "Third Sand", being generally designated as the "Third Bradford Sand". Its static aspects are porosity, permeability and saturation. At the present time, water flooding is the process employed to produce oil in the Bradford Field. This process is based upon the interplay of forces in the system sand-stone-oil-water.

The average Third Bradford Sand consists of a polyphase mixture of heterogeneous mineral grains, cemented to various degrees of compactness by other mineral compounds. Between grains are found interstitial voids (pores) which may be completely or partially filled by water or oil. The amount of these pore spaces constitutes the porosity of the sand. Oil saturation indicates the percentage of pores occupied by oil, whereas permeability is defined as "the ease with which fluids may traverse the (porous) medium under the influence of driving pressure."

Kerogen from shale and petroleum or crude oil from sandstone are entirely different in composition and the methods heretofore used in the recovery of each have likewise been varied and different.

Four methods have been used in Sweden by Svenska Skifferolje A.B. for the recovery of organic substances, generally known as kerogen, from shale deposits. One of these methods, known as the Ljungstrom In-Situ Method, or Electrotbermic Process, creates pyrolysis in the ground through use of electric energy as heat. It was hoped that this method would prove successful and economical in the recovery of residual oil reserves from the Bradford Third Sand and the conferences in Sweden were held for the prime purpose of determining the extent to which the use of the Ljungstrom In-Situ Method would prove beneficial.

As stated in my letter to the Svenska Skifferolje A. B., under date of July 7, 1947, a minimum of 400,000,000 barrels of residual oil remains in place in the Bradford Third Sand that cannot be recovered by present known methods. Competent authority has recently estimated these residual reserves to exceed 600,000,000 barrels of oil.

In the event a method can be found whereby any substantial percentage of the above stated residual oil reserves (600,000,000 barrels) can be recovered economically, a new oil field will, in effect, have been discovered. It is to this end that research has been going forward at an accelerated pace for several years past.

The foregoing explanation is given for the purpose of fully impressing upon the members of the Svenska Skifferolje A.B. our sincere desire and ambition to find a method whereby residual oil reserves may be recovered economically. We, of the Bradford group, are of the opinion that any method, having even the slightest chance of recovering residual oil reserves at a profit, must be investigated

and, if it is found that such a method can possibly yield satisfactory results in the foreseeable future, such method should be exploited to final determination.

It is natural that our first interest has been devoted to the recovery of residual oil from the local Bradford Oil Field, partially by reason of present investments in property, machinery and equipment and further due to the enormous wealth of data that has been accumulated throughout the years. Our investigation has, however, included possibilities that may exist in other oil and gas bearing formations, including shale, in the United States.

We had hoped that our investigation in Sweden would bring forth a means whereby the Ljungstrom In-Situ Method could be used commercially and yield economic results. The closest spacing which we can reasonably consider for use between wells is 104 feet. The Third Bradford Sand formation is 7 to 100 feet in vertical thickness and is found at elevations 1,100 feet to 2,100 feet beneath the surface of the ground, or at an average of 1,550 feet. Labor costs in the Bradford area are much higher than similar costs in Sweden. Electric energy cannot be purchased locally for much less than \$.01 per KWH under any circumstance.

A copy of the tariff issued by the Public Service Commission of Pennsylvania to Pennsylvania Electric Company, holders of the franchise for distribution and sale of electric energy in the Bradford area is herewith enclosed under caption "Electric Energy Tariff".

In your booklet entitled "Svenska Skifferolje A.B., Orebro, Sweden", published by Ludvig Larsson Boktryckeri in 1948, at page 10,



appears the following memorandum:

"The electrothermic method is based upon the availability of sufficient quantities of comparatively cheap electric power".

At the present time we are being paid at the rate of \$4.10 per barrel (42 gallons) for crude oil, which price is higher than generally may be expected. A schedule entitled "Bradford Oil Field- Annual Average Crude Oil Price" is herewith enclosed for the purpose of showing the price paid for crude oil during the past 30 years. You will note that the average price for the 30 year period is \$3.14, for the 20 year period, \$2.88, and for the past 10 years, \$3.44 per barrel.

A hypothetical test employing the Ljungstrom In-Situ Method upon property in the Bradford Oil Field has been projected for the purpose of establishing economics affecting the same, under the following assumptions:

A. PATTERN

1. Pattern - Hexagonal 7-spot;
2. Spacing - 104' heat to heat or heat to producer;
3. Total area to be heated and produced at the same time - 40 acres;
4. Total number of heat wells - 124;
5. Total number of producers - 62;
6. Depth of wells - 1500';

B. FORMATION AND PAY

1. Vertical formation thickness to be heated - 50';
2. Net pay sand thickness to produce - 40';
3. Average pay sand porosity - 15%;

5. Sale price of crude oil recovered - \$3.50 per barrel.

**C. DEVELOPMENT AND OPERATION**

1. Complete redrilling of property using present day costs;
2. Heat wells to be cored but not shot;
3. Producing wells to be shot and equipped with present day pumping units;

**D. HEATING DATA**

1. Formation temperature now 68°F.
2. Formation temperature to be increased approximately 70°F. to 140°F.
3. Heating element 50' long;
4. Demand per heating element - 18 KW.

**E. ELECTRICAL DATA**

1. Cost of electrical energy under rate #41 of Pennsylvania Electric Company;  
(Franchised distributor of electrical energy)

**NOTE:** Copy of rate tariff as filed with Public Utility Commission of Pennsylvania, included herewith.

2. Average cost of electricity during life of project at Bradford, Pennsylvania, rates \$.0098 per kWh.
3. Total demand for 124 heat wells - 2,235 KW.
4. Total average energy per month - 1,610,000 KWH.
5. Electric energy required, allowing 20% heat loss, 1,900,000 KWH per acre or 76,000,000 KWH for 40 acres.
6. Formation temperature increase to 140°F.
7. Electric energy cost - \$18,850.00 per acre, or \$6,080.00 per heat well.

**SUMMARY OF TOTAL COSTS**

**ESTIMATED INVESTMENT COSTS - PER ACRE**

Heat and producing wells, drilled and equipped,

Electric lines and equipment, oil storage and run  
tanks and other miscellaneous costs per acre \$29,080.

#### ESTIMATED OPERATING COSTS - PER ACRE

Maintenance, replacement and miscellaneous oper-  
ating costs including electricity \$26,120.

Total Investment and Operating Costs per acre \$57,200.

#### CONSIDERATION OF ECONOMICS

Assuming there is no royalty to pay, the total recovery re-  
quired to break even only, would be 18,500 barrels per acre, or 41  
barrels per acre foot of net pay. This means that to break even the  
oil saturation in the pay must be reduced down to a residual satur-  
ation of 14.9%. It is deemed impossible to reduce the residual satur-  
ation to 14.9% by only raising the formation temperature 70°F. (as  
to 140°F.).

The foregoing calculation was based upon the development  
and operation of a so-called virgin or previously undeveloped oil  
producing property in the Bradford oil field, Warren County, Pennsyl-  
vania, i.e., before the property had been subjected to any type of  
water flooding or secondary method of development.

The problem in the Bradford Oil Field is to recover oil from  
so-called depleted oil sands where the residual oil saturation is  
found to be 36% or less at the present time. The oil bearing forma-  
tion in the majority of these properties contains a large volume of  
water which must be moved in order that the oil may be recovered,  
which condition causes additional operating problems and expense.

Electric energy used at Kvarntorp with shale is 1,017 KWH  
per barrel of crude oil. At the Bradford rate of \$.01 per KWH, elec-  
tric energy alone would cost \$10.17 per barrel of crude produced.

Accordingly, if 16,300 barrels of oil must be recovered (at \$3.50 per barrel) in order to break even upon the development and operation of a property, the project is uneconomical to such a serious degree that no attempt should be made to operate a field test or to otherwise employ the use of the Ljungstrom In-Situ Method in the Bradford Oil Field at the present time or in the foreseeable future. A drastic reduction in the cost of electric energy could alter this decision materially, however, such a reduction does not appear possible for some time to come.

In view of the foregoing information, and as a result of an investigation, the group of interested parties from Bradford, Pennsylvania, who were joined together for the purpose of investigating the feasibility for use of the Ljungstrom In-Situ Method, have requested that I inform you of their decision to dispense with further interest in the use of the Ljungstrom In-Situ Method for use in the Bradford Oil Field and other oil and gas bearing formations, including shale, in the United States and Canada. Their decision has been predicated upon the exceedingly high cost for electric energy in the Bradford area, and further upon the high costs applicable to the drilling and equipping of wells locally.

We, of the Bradford group, extend our most sincere thanks and compliments to the very able executive officers and technical experts of Sevenska Skifferolie A.B.. They performed their duties perfectly and were most generous and genial in their effort to afford us knowledge concerning your operation. It would indeed be difficult to name your most able representative, as their individual and collective services were exceedingly well performed.



Please extend our sincere thanks also to Gunnar W. Anderson and Haldor Nordgaard, for the excellent services rendered by them in attempting to procure a satisfactory agreement in behalf of Svenska Skifferolje A.B. and Svenska Entreprenad A.B., with the Bradford group.

In appreciation for all you have done in our behalf, may I suggest that you grant us the privilege to reciprocate in the event we can ever be of service to you.

Respectfully submitted,



Victor H. Samuelson

ca  
bor-  
hela  
ame-  
berget  
ytter-  
att få  
olja  
oljans  
var läm-  
in sit  
därvid  
borr-  
olika  
topo-  
vit för  
oden  
orterat  
ljessand  
hammar-  
dika  
2 och 3  
ills em  
ovisas  
etisk  
-4).

## BRADFORD GLE FIELD

## ANNUAL CRUDE OIL PRODUCTION

YEAR	BARRELS	YEAR	BARRELS
1871	1,000	1910	2,128,000
1872	2,000	1911	2,152,000
1873	2,000	1912	2,177,000
1874	3,000	1913	2,204,000
1875	25,000	1914	2,230,000
1876	382,768	1915	2,256,000
1877	1,468,481	1916	2,282,000
1878	6,208,746	1917	2,308,000
1879	13,914,509	1918	2,334,000
1880	22,212,000	1919	2,360,000
1881	22,945,069	1920	2,386,000
1882	17,959,000	1921	2,415,000
1883	13,294,886	1922	2,577,726
1884	11,983,000	1923	2,602,777
1885	10,564,293	1924	2,480,540
1886	9,752,797	1925	2,747,620
1887	7,520,979	1926	4,725,252
1888	5,306,062	1927	5,793,707
1889	5,765,053	1928	6,361,703
1890	5,635,735	1929	8,137,125
1891	5,432,413	1930	9,284,230
1892	4,281,061	1931	8,812,133
1893	3,502,136	1932	9,964,235
1894	3,359,835	1933	10,125,458
1895	3,244,808	1934	11,990,248
1896	3,204,771	1935	15,183,322
1897	3,204,230	1936	14,569,740
1898	3,204,230	1937	16,738,688
1899	3,206,845	1938	15,088,663
1900	3,022,493	1939	14,594,612
1901	2,767,603	1940	14,285,014
1902	2,506,981	1941	13,397,753
1903	2,322,413	1942	15,532,472
1904	2,187,883	1943	13,684,136
1905	2,117,225	1944	12,162,521
1906	2,22,000	1945	10,792,985
1907	2,048,000	1946	11,756,513
1908	2,074,000	1947	11,512,061
1909	2,100,000	1948	11,173,528
		1949	9,783,553

TOTAL BARRELS OF OIL PRODUCED 1871-1949

523,852,446

ta

por-

hala

sma-

berget

ytter-

att få

olja

oljans

har läm-

s in situ

g därvid

berr-

olika

topo-

ivrit före-

toden

porterata

oljesamla-

samman-

dika

2 och 3)

ills enlast

lovisas

etisk

4).

# BRADFORD OIL FIELD

## ANNUAL AVERAGE CRUDE OIL PRICE

YEAR	PRICE	PRICE	PRICE
1920	\$5.867		
1921	3.328		
1922	3.175		
1923	3.323		
1924	3.695		
1925	3.762		
1926	3.765		
1927	3.156		
1928	3.360		
1929	3.947		
1930	2.596	\$2.596	
1931	2.022	2.022	
1932	1.881	1.881	
1933	1.860	1.860	
1934	2.460	2.460	
1935	2.176	2.176	
1936	2.570	2.570	
1937	2.620	2.620	
1938	1.898	1.898	
1939	2.059	2.059	
1940	2.287	2.287	\$2.287
1941	2.565	2.565	2.565
1942	2.942	2.942	2.942
1943	3.000	3.000	3.000
1944	3.312	3.312	3.312
1945	3.750	3.750	3.750
1946	3.825	3.825	3.825
1947	4.210	4.210	4.210
1948	4.971	4.971	4.971
1949	3.561	3.561	3.561
TOTAL NO. YEARS	30	20	10
AVERAGE PRICE	3.14	\$2.83	\$3.44

NOTE: AVERAGE FOR 3 PERIODS \$3.14

A.  
sta  
spor-  
hala  
game-  
berget  
ytter-  
ätt få  
olja  
oljans  
har läm-  
in situ  
g därvid  
borr-  
olika  
- topo-  
divit före-  
toden  
porterats  
oljesanda-  
resman-  
lika  
2 och 3)  
hills emlast  
dovisen  
retisk  
S-4).



Bradford - projektet.

(Slutrapport)

Vid utvinning av olja ur de oljeförande bergartarna i U.S.A. och annorstädes är utbytet i regel lågt. Under utvinningsens första stadium, då oljan med självtryck eller med hjälp av pumpar transporteras upp till markytan, erhåller man i runt tal en tredjedel av hela den tillgängliga oljekvantiteten.

Man började därför ganska snart komplettera denna utvinningsmetod med s.k. secondary recovery, innebärande en utspolning av i berget kvarvarande olja med vatten eller ibland med gas (naturgas). Ung. ytterligare en tredjedel av den totala oljemängden kan man på detta sätt få upp, medan alltså den sista tredjedelen kvarstår i berget.

Efterhand som de rikaste källorna tappats och efterfrågan på olja stigit har man börjat intressera sig för effektivare metoder för oljans utvinning. Ett uppdrag till förbättring av "secondary recovery" har lämnats av dr. Ljungström, enligt vilket oljesanden skulle uppvärmas in situ på elektrotermisk väg. Genom att oljans viskositet och ytspänning därvid sänkas, kan man vänta sig, att den lättare skall rinna fram till borrhälen.

Vid bedömandet av detta förslag måste hänsyn tagas till de olika faktorer, som inverkar på dess genomförbarhet, nämligen geologisk-topografiska, ekonomiska och tekniska faktorer. Samtliga dessa ha blivit föremål för särskilda utredningar.

De naturliga förutsättningarna, dvs. belägenheten av för metoden lämpliga förekomster av oljesand i U.S.A. har undersökts och rapporterats av civiling. O. Ljungström (Bradfordrapport 1 - 2). Beträffande oljesandförekomster i Canada har en (visserligen ofullständig) litteratursammanställning gjorts av undertecknad (Rapport OS-1.)

Metodens ekonomiska förutsättningar har utretts med något olika utgångspunkter, dels av civiling. O. Ljungström (Bradfordrapport 2 och 3) dels av undertecknad (Rapport OS-2).

Vad slutligen de tekniska möjligheterna beträffar, har hittills endast vissa laboratorieundersökningar kunnat göras, vilkas resultat redovisas i rapport OS-3. De resultat, som erhöles föranledde även en teoretisk utredning om strömningsförhållandena i porösa kroppar (Rapport OS-4).

Ennå naturligtvis vissa slutsatser kunna dragas ur de erhållna resultaten är det dock fullt klart, att dessa uträkningar måste kompletteras med fältförsök i ej alltför liten skala. Man kan nämligen ej med provstycken om några  $\text{cm}^3$ s volym erhålla en tillförlitlig bild av förhållandena i berg med en volym av flera miljoner  $\text{m}^3$ .

För överskådliggighets skull ges här ett mycket kortfattat sammandrag av de olika rapporternas innehåll.

#### Naturliga förutsättningar:

En typisk och ur flera avseenden lämplig oljesandförekomst i U.S.A. är Bradford i Pennsylvanien. Sanden har en mäktighet å djupled av 10-20 meter och en kvavvarande oljehalt av cirka 4 volym-%. Den ligger dock på ett stort djup, 400-500 meter.

Bland Canadas enorma tillgångar av oljesand synes förekomsten i Athabaska i norra Alberta vara en av de bäst belägna. Sanden har här en mäktighet av 30-60 meter och en oljehalt av 0-25 vikta-% (ingen olja har hittills uttagits). Djupet varierar också här starkt, men stora delar av Athabaska-sanden gå ända upp i dagen.

#### Ekonomiska förutsättningar:

I fråga om Bradford tycks de av det stora djupet betingade höga borrhkostnaderna bli den avgörande utgiftsposten. Detta medför, att produktionskostnaderna pr utvunnenbarrel olja bli relativt höga. I O. Ljungströms rapport 3 har erhållits en beräknad produktionskostnad av \$ 4,80 pr barrel, i undertecknads rapport OS-2 en kostnad av \$ 4,2 + 5,2 pr barrel. Marknadspriset i U.S.A. är enligt uppgift \$ 5,- pr barrel.

#### Tekniska förutsättningar:

Enligt den vedertagna Darcy's lag, skulle flödet genom oljesanden vara omvänt proportionellt mot vätskans viskositet och en temperaturhöjning skulle alltså öka flödet i samma takt som viskositeten sjunker. Inga experimentella bevis härför har rapporterats i facklitteraturen. Försöken vid vårt laboratorium ha nu visat, att flödet visserligen stiger vid en temperaturhöjning, men ej på långt när så mycket som motsvarar viskositetsändringen. Såvitt med de relativt primitiva anordningar, som stått till buds, kunnat konstateras, gäller alltså Darcy's lag icke. Samma resultat har även erhållits i den nämnda teoretiska behandlingen av problemet.

#### Sammanfattning och förslag:

Så långt man kan bedöma av här föreliggande uträkningar äro förutsättningarna i Bradford ej tillräckligt gynnsamma för den elektrotermiska metoden. Med hänsyn till den stora betydels metoden skulle kunna få i dagens oljesituation vore det emellertid synnerligen önskvärt med fältförsök i mindre skala. Dessa skulle emellertid förläggas till en plats med oljesand på relativt ringa djup för att försökskostnaderna ej skulle

bli för höga. En sådan plats bör kunna uppletas i samarbete med de intresserade kontaktnätn i U.S.A., som redan ha intresse för saken.

Vidare synes det vara lämpligt, att under tiden närmare undersöka Canadas oljesandeförekomster. Enligt vederhäftiga källor (citerade av Max W. Ball i en artikel 1941) skulle Canada ha oljetillgångar i skiffer och oljesand på  $100 - 250 \cdot 10^9$  barrels, dvs. betydligt mer än hela den övriga världens sammanlagda oljetillgångar. Exploateringen av dessa förekomster är emellertid föga utvecklad. Ball uppger, att med dittillvaranda metoder (år 1941) endast några promille av hela oljemängden kunde utvinna ekonomiskt. Måhända vore därför Canada också den gynnsammaste platsen för det fältförsök, som ovan föreslagits.

Norrköping den 24.11.48.

*Erik Selin*

Bilagor: rapport OS-1,-2,-3,-4.

## Oljesandförekomster i Canada.

Uppgifterna i facklitteraturen betr. Canadas oljesandförekomster äro ej på långt när så rikliga som om U.S.A:s oljesand. Detta är emellertid ett tecken, ej på förekomsternas ringa omfattning, utan snarare på att deras tekniska utnyttjande ännu knappast har lämnat experimentstadiet.

Med tanke på ev. möjligheter att i Canada tillämpa den s.k. Ljungströmsmetoden har nedan gjorts en kortfattad litteratursammanställning av de uppgifter som varit åtkomliga. Rapporten är avsedd att ge en uppfattning om förekomsternas belägenhet, geologi, omfattning och art samt om den hittillsvarande bearbetningen. Den bygger i huvudsak på Max. W. Bells utförliga artikel i Canadian Mining and Metallurgical Bulletin Febr. 1941 (1).

### Oljesandens läge.

Canadas oljesandförekomster ligga i norra Alberta i Athabaska-området (fig. 1.) Området utgöres av en höglätt av präriestyp, i vilken Athabaska River och dess biflöder ha skurit ned djupa, tränga dalar, nästan canyons. Oljesanden ligger under en stor del av höglätten och går i dagen i floddalarna. Centrum för de kända förekomsterna ligger

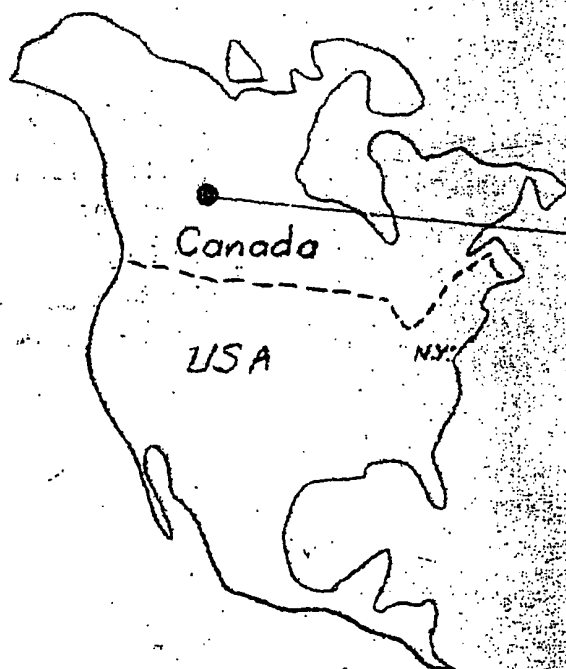
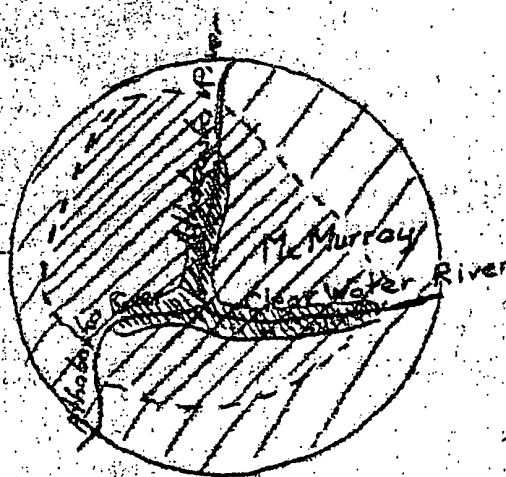


Fig. 1






-  oljesand i dagen
-  troliga oljesandförekomster
-  möjliga oljesandförekomster

Fig. 2.

i sammanflödet mellan Athabaska River och Clearwater River (fig 2.). Efter forstet Mc Murray benämndes fyndigheten ofta Mc Murray-formationen.

Kommunikationerna äro goda och bestå i järnvägsförbindelse söderut till staden Edmonton och båtförbindelse norrut nedför Athabaska River. Klimatet tillåter drift av där befintliga anläggningar året runt. Årsmedeltemperaturen är ca.  $\pm 0^{\circ}\text{C}$ .

#### Fyndighetens omfattning.

(Då hittills endast i dagen gående fyndigheter ha varit av aktuellt intresse är kännedomen om underjordisfyndigheter högst ofullständig och inskränker sig ofta till rena uppskattningar).

Oljesandalagret är 100-200 feet djupt och har en säker utsträckning av 10.000 square miles, ev. ända till 30.000 sq. miles. Oljehalten varierar mellan 0 och 25 vikta-% med ett genomsnittsvärde av ca. 17 vikta-% i hittills analyserade prov. En på dessa siffror grundad, mycket försiktig beräkning av totala oljemängden ger siffran 100 - 250  $\cdot 10^9$  barrels olja. Som en jämförelse kan nämnas, att U.S.A:s oljetillgångar i början av 1940 beräknades till 18,5  $\cdot 10^9$  barrels och hela den övriga världen till 16,9  $\cdot 10^9$  barrels.

#### Geologi.

Oljesanden ligger underst i kritperiodens geologiska lager, närmast över Devon-skiktet. Över oljesanden ligger i flera lager ljusa och mörka skiffrar, sandsten m.m. Där hela lagerserien kvarstår utan att ha blivit avnött genom erosion är djupet till oljesanden ca. 1800 feet, men, som ovan framhållits har erosionen varit kraftig på grund av de översta lagrens relativt mjuka beskaffenhet. Tjockleken av de över oljesanden liggande lagren synes minska något sydväst ut från Mc Murray. Det under oljesanden liggande Devonlagret utgöres av en hård kompakt kalksten med en ansenligsvärd jämn, horisontell övre yta.

#### Sandens egenskaper.

Oljesanden utgöres här av kvartekorn, sammankittade av olja. Någon annan kittsubstans finns ej, varför sanden sönderfaller till ett löst, "sockrigt" material, då oljan borttages. Oljan fyller icke ut porerna, utan omger de enskilda kornen som en film. Förmodligen ligger dock närmast kornen, innanför oljefilmen, en tunn vattenfilm (2, 3).

### Oljans egenskaper.

Oljan är av helt annan typ än U.S.A:s petroleum. Den är svart, asfaltliknande och så viskös, att den ej flyter vid rumstemperatur. Färsk (icke oxiderad) olja har en spec.vikt av 1,00-1,02. Den är mycket känslig för upphettning, varigenom den förändras och blir mera lättflytande. Genom termisk vätskefas-krackning kan man få upp till 40 % bensin, utan att därför förlusterna i form av koks och gas bli högre än ca. 40 %. Bensinen är lätttraffinerad och har ett ovanligt högt oktantal (77-82) utan särskild behandling eller tillsatser.

Dessa oljans egenskaper anses tyda på att den är ett ursprungligare mineral än petroleum och att den ej genomgått samma naturliga krackningsprocesser som vanlig petroleum.

### Utnyttjningsmöjligheter.

Ball diskuterar de olika möjligheter, som kunna tänkas för utvinning av oljan och kommer till följande slutsatser:

1) Utvinning av oljan måste ske genom brytning av sanden. (Pumpning, förträngning med vatten och dylika metoder äro oanvändbara på grund av oljans tjockflutenhet.)

2) Brytningen kan blott ske, där sanden går i dagen. Sanden och överliggande bergarter äro för lösa för att man skulle kunna öppna schakt utan ett dyrbart stämpningsarbete. Ej heller brytning i horisontella tunnlar är möjligt. Ej ens alla förekomster som "gå i dagen" i floddalarna kunna brytas. På många ställen är sanden nämligen täckt av ett alltför tjockt lager "overburden" (grus, sand och lera) som skulle bli alltför dyrt att avrymma. Avrymningskostnaderna sätta en övre ekonomisk gräns vid en "overburden" av en cu.yard pr ton brutna sand. Därtill kommer att det mycket ofta saknas plats för uppläggning av de avrymda massorna och den bearbetade sanden. Slutligen finns på många ställen i floddalarna ingen plats, där fabriksanläggningarna kunna byggas. Av dessa orsaker ha de mest markerade oljesandförekomsterna längs Athabaska River inget ekonomiskt värde!

Detta gör, enl. Ball att man av Canadas stora oljetillgångar med hittills (1941) kända metoder ej kan tänka sig att utnyttja mer än högst någon promille.

3) Torrdestillation av den brutna sanden skulle bli för dyrbar och samtidigt ej tillräckligt skonsam för den temperaturkänsliga oljan.

4) Extraktion med lösningsmedel skulle bli alltför dyr på grund av svårigheterna att återvinna lösningsmedel ur sanden.

5) Den enda hittills framkomna användbara metoden består i omrörning av sanden i kallt vatten. Oljan skiljer sig lätt från sanden, men flyter ej upp till ytan.

grund av sin höga specifika vikt. Detta åstadkommes genom flotering med luft.

#### Försöksanläggning.

Efter många års prövande av olika metoder i liten skala startades 1930 Abasands Oils Limited, som utarbetat den ovannämnda varm-vatten-metoden och överfört den i halvstor skala. Anläggningen, som är detaljerat beskrivet i Balls artikel (1) är avsedd för en kapacitet av 400 ton sand/dygn, motsvarande 350 barrels olja/dygn ( $\approx 55 \text{ m}^3/\text{dygn}$ ).

Av intresse är att notera, att anläggningen skall producera sitt eget behov av elkraft med en kraftcentral, eldad med krackningsgaser och koks från raffinaderiet.

Anläggningen började byggas 1937, men kunde av olika anledningar ej köras igång förrän 1942. Clark(3) anger emellertid i juni 1944, att anläggningen fortfarande ej fungerar tillfredsställande (beroende på principiella svagheter i metoden) och måste omkonstrueras.

Samma firma har planerat en anläggning i större skala för en produktion av 10.000 barrels/dygn ( $\approx \text{ca. } 1600 \text{ m}^3/\text{dygn}$ ). Följande beräknade anläggningskostnader kunna vara av intresse:

Produktionsanläggningen	\$ 4.500.000
Rörledning till Edmonton (300 miles)	" 350.000
Raffinaderi i Edmonton	" 3.150.000
<u>Totala anläggningskostnader</u>	<u>\$ 8.000.000</u>

#### Litteratur:

- (1) Max. W. Ball: Development of the Athabaska Oil Sands. Canadian Mining and Metallurgical Bulletin (febr. 1941) nr. 346: 58-91.
- (2) Max. W. Ball: Athabaska Oil Sands: Apparent Example of Local Origin of Oil. Bull. Am. Assoc. Petroleum Geologists (1935) 19:153-171
- (3) K.A. Clark: Hot-water Separation of Alberta Bituminous Sand. Canadian Mining and Metallurgical Bull. (juni 1944) nr. 386 257-279.
- (4) K.A. Clark: Bituminous Sands of Alberta. Oil Weekly 118 (1945) nr. 46-51.

#### Kommentar till rapporten.

Att döma av de uppgifter, som stått till buds i facklitteraturen har alltså Canada stora förekomster av högvärdig oljesand, men saknar fortfarande



användbara utvinningsmetoder. På grund av oljans egenskaper kunna de i U.S.A. tillämpade metoderna ej överflyttas till Canada. Förutsättningarna för den elektrotermiska metoden synes vara förhanden. En svårighet därvid är, att tillgången på utbyggd elkraft i de aktuella områdena torde vara fullständigt obefintlig. Denna fråga bör dock kunna lösas med hjälp av den goda tillgången på vattenkraft eller med ångkraft ur krackgaserna från raffinaderiet (vilken gaser här i Ödemarken ej kunna få någon annan användning).

På andra sidan är det många faktorer, som direkt peka på en in-situ-metod som enda framkomliga vägen.

Av de citerade artiklarna har man också kunnat utläsa, att de kanadensiska myndigheterna hysa det allra största intresse för oljesandens utnyttjande.

Norrköping den 30.11. 1948.

*Carl Selander*